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THE
PLAY BOOK
OF
METALS
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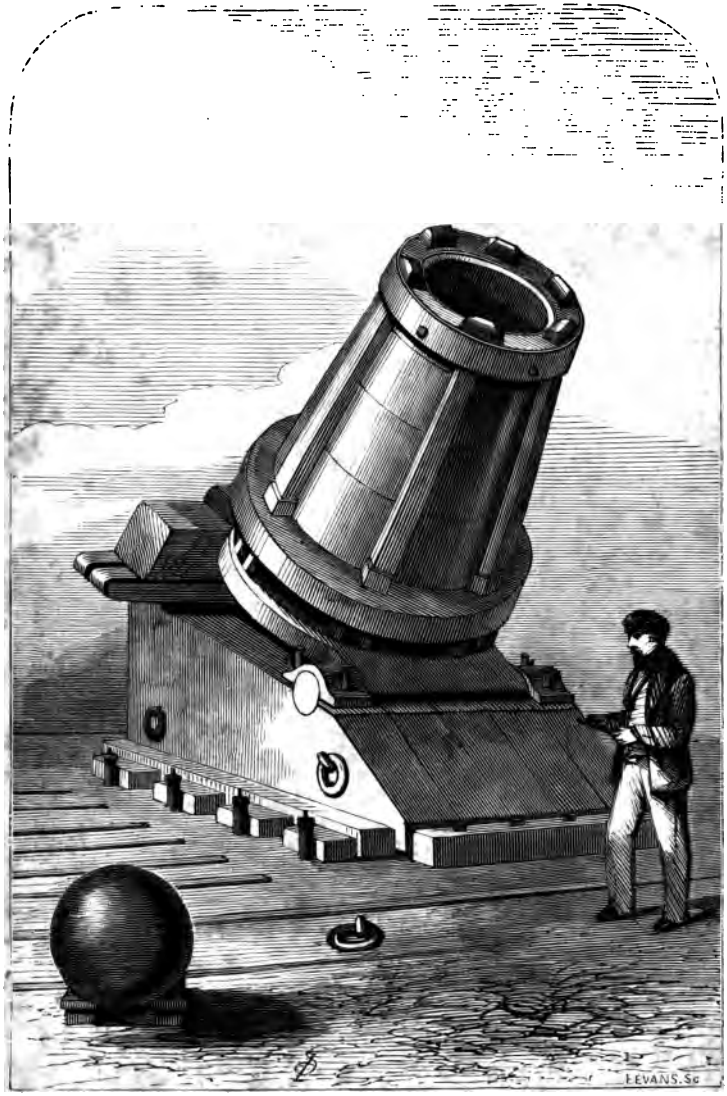

MALLET'S MORTAR.

THE

PLAYBOOK OF METALS:

INCLUDING

PERSONAL NARRATIVES OF VISITS TO COAL, LEAD, COPPER, AND TIN MINES;

WITH

A Large Number of Interesting Experiments

RELATING TO ALCHEMY AND THE CHEMISTRY OF THE FIFTY METALLIC ELEMENTS.

BY

JOHN HENRY PEPPER,

F.C.S., A. INST. C.E., LATE PROFESSOR OF CHEMISTRY AT THE ROYAL POLYTECHNIC, AUTHOR OF "THE PLAYBOOK OF SCIENCE."

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TO

WALTER HUGHES, ESQ.

SOUTHWOOD, HIGHGATE.

My dear Sir,

As a slight token of my grateful esteem, permit me to dedicate these pages on elementary science to you, and with sentiments of sincere regard and respect, to subscribe myself

Your Faithful and Obliged Friend,

JOHN HENRY PEPPER.

CONTENTS.

PAGE

INTRODUCTION 1

CHAPTER I.

COAL AND COAL MINES 3

CHAPTER II.

THE ART OF ALCHEMY THE PREFACE TO THE SCIENCES OF CHEMISTRY AND METALLURGY 116

CHAPTER III.

THE METALS AND THEIR COMBINATIONS 152

CHAPTER IV.

GOLD 168

CHAPTER V.

SILVER 209

CHAPTER VI.

LEAD 233

CHAPTER VII.

COPPER 259

PAGE

CHAPTER VIII.

TIN, ANCIENTLY CALLED JUPITER 294

CHAPTER IX.

MERCURY 318

CHAPTER X.

IRON 338

CHAPTER XI.

ALUMINIUM 395

CHAPTER XII.

ANTIMONY 416

CHAPTER XIII.

ARSENIC 424

CHAPTER XIV.

BARIUM 434

CHAPTER XV.

BISMUTH 438

CHAPTER XVI.

CADMIUM 441

CHAPTER XVII.

CALCIUM 442

CHAPTER XVIII.

CERIUM 447

PAGE

CHAPTER XIX.

CHROMIUM 448

CHAPTER XX.

COBALT 450

CHAPTER XXI.

DONARIUM, DIDYMIUM, ERBIUM, GLUCINUM, ILMENIUM, IRIDIUM, LANTHANIUM, AND LITHIUM 454

CHAPTER XXII.

MAGNESIUM 457

CHAPTER XXIII.

MANGANESE 460

CHAPTER XXIV.

MOLYBDENUM 464

CHAPTER XXV.

NICKEL 466

CHAPTER XXVI.

NIOBIUM, NORIUM, OSMIUM 471

CHAPTER XXVII.

POTASSIUM 472

CHAPTER XXVIII.

PLATINUM 476

CHAPTER XXIX.

PALLADIUM, PELOPIUM 479

PAGE

CHAPTER XXX.

RHODIUM, RUTHENIUM 482

CHAPTER XXXI.

SODIUM 483

CHAPTER XXXII.

STRONTIUM 486

CHAPTER XXXIII.

TANTALUM, TELLURIUM, TERBIUM, THORIUM, TITANIUM . . . 488

CHAPTER XXXIV.

TUNGSTEN 490

CHAPTER XXXV.

URANIUM, VANADIUM, YTTRIUM 492

CHAPTER XXXVI.

ZINC 494

CHAPTER XXXVII.

ZIRCONIUM 503

CHAPTER XXXVIII.

GENERAL REMARKS 504

INTRODUCTION.

THE very flattering reception accorded to the "Boy's Playbook of Science" has encouraged the author to endeavour to complete the popular sketches not only of the great and imponderable powers of Nature called Gravitation, Cohesion, Chemical Affinity, Heat, Light, Electricity, and Magnetism, but likewise to grapple with that very wide field of inquiry comprehended in the subject of "Mines, Minerals, and Metals." This theme involves the consideration of the *fifty metallic elements*, which were wholly omitted in the "Boy's Playbook;" the *thirteen non-metallic elements*—viz., Oxygen, Hydrogen, Nitrogen, Chlorine, Iodine, Bromine, Fluorine, Carbon, Boron, Silicon, Selenium, Sulphur, and Phosphorus—being alone treated of in that portion of the work devoted to the subject of Chemical Affinity; and as the author has had the pleasure of visiting several Coal, Copper, Lead, and Tin Mines, the personal narratives of those visits may be of service to the youthful reader, who may be stimulated to go over the same ground, and thus become practically acquainted, by personal observation, with facts that are not likely to be easily forgotten afterwards. A tour through the mining districts certainly impresses the mind with the vast commercial results that can be obtained by persevering industry and determination, coupled with scientific knowledge, and an inspection of the engineering details shows what apparently insurmountable difficulties have been overcome. Such an example as the great Dukinfield Coal Mine, in Cheshire, which is more than two thousand feet deep, and occupied the proprietor twelve years in boring and digging it, at a cost of 100,000*l.*, is only one amongst other and similar brilliant industrial triumphs won at the almost inaccessible depths of the rock-formed crust of the earth; whilst the fact of the

value of the raw mineral products of Great Britain and Ireland being estimated at about thirty millions sterling per annum, offers a further inducement to the youthful reader to inquire how this mineral portion of the dust of the earth is transmuted into such heaps of the precious metal gold. Even if we disregard the strictly scientific portion of the subject of the metals, the contemplation of the numerous useful purposes to which they are applied is exceedingly amusing and instructive; thus our houses contain all kinds of iron ware, stoves, grates, fire-irons, locks, tin-plate ware, brass furniture, lead pipes, coppers, bells, wires, lamps, Britannia metal, silver plate, electro-plated articles, jewellery, pins, needles, cutlery, gold, silver, and copper coins, and silvered looking-glasses.

The same metallic articles are all more or less contained in the huge floating arks propelled by steam power, with the addition of great chain cables, anchors, copper sheathing, compasses; or, when used for warlike purposes, guns, swords, pistols, cannon, rifles, shot, shell, and bullets.

Again, in the more peaceful arts, there are the plough, husbandry implements, machines, horse-shoes, tools, nails, screws, wire-work, type, telescopes, microscopes, and other instruments, clocks, watches, trinkets. In the fine arts, coinage, copper and steel engraved plates, zinc plates, bronze and other metallic statues. And, to conclude a list which seems endless, all the most stupendous forms of machinery, the steam-engines, railways, suspension bridges, tubular bridges, and last, but not least, the steam-horse, the locomotive, composed of 5416 pieces all fixed together, and working as delicately as the finest bit of clockwork. These applications represent the mechanical value of the metals, but do not include the almost equally important chemical metallic compounds indispensable in the noble science of Medicine, in Chemistry, and in the useful arts of dyeing, calico-printing, the colouring of glass, china, pottery, and the thousand other requirements of this civilized but luxurious age.

The author desires here to express his obligations to Professor Tennant, Mr. Evan Hopkins, and Professor Ansted, for much valuable information, and recommends his readers to consult the more advanced works on Geology, Mineralogy, Metallurgy, and Chemistry of Lyell, Richardson, Phillips, Nicol, Scoffern, Clay, Oxland, Ure, Abel, Bloxam, and Muspratt.

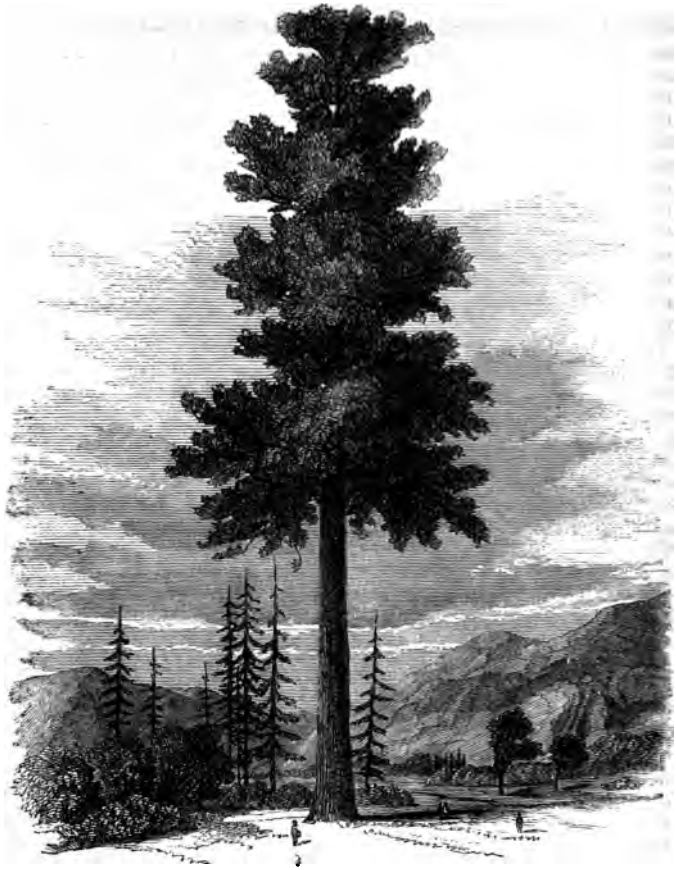


Fig. 1. Wellingtonia Gigantea in the Crystal Palace.

CHAPTER I.

COAL AND COAL MINES.

THE chief intention of this second "Playbook of Science" is to introduce the important class of elements called the metals to our youthful readers, and as nearly the whole of them, in their natural and mineral state, are, as it were, invisible, by reason of their combination with other

elements, which mask and conceal their metallic properties, it behoves us to inquire what are the usual means resorted to for the purpose of releasing the metals from their union with oxygen or sulphur, or other common elements, and restoring to them with their liberty the important qualities of brilliancy, malleability, ductility, and tenacity. The answer to the previous query might be made at considerable length, if the processes of the solution of the minerals by acids, as performed in our laboratories, were fully described. We shall not, however, anticipate these chemical details, which are better explained with each metal, but will confine ourselves at present to that potent talisman "Coal," at whose bidding, and whilst in a state of combustion, the minerals are decomposed and liquefied, and their gritty, brittle, stony qualities changed to those of tractility and extensibility. Coal is the commercial substance specially required to obtain the useful metals. Coal, as Vischers remarks, is now the indispensable *aliment* of industry; it is a primary material, engendering force, giving a power superior to that which natural agents, such as water, air, &c., procure. It is to industry what oxygen is to the lungs, water to the plant, nourishment to the animal. It is to coal we owe *Steam* and *Gas;* it replaces, in the workshops and the domestic hearths, the charcoal which had become too costly. Under the last head, in our northern latitudes, it is destined always to acquire increasing and more general use. The employment of coal will henceforward be no other than a question of cheapness; as, in the present age, the first interest of industry is, above all, to see ameliorated the ways of communication—to lower the tolls upon the routes and the canals. *If custom-house officers still oppose shackles on manufactured products, they lower their barriers for the passage of the raw material.*

It is the lovers of antiquities, the laborious and painstaking antiquaries, who search out, recover, and rebuild in imagination the giant castles, the abbeys, the nunneries, that once reared their proud pinnacles, towers, and battlements in our land, and were peopled with men and women who, although differing in dress, manners, and learning with ourselves, possessed the same feelings of love and hatred, piety and profanity, simplicity and vanity, which abound in the well-dressed and educated society of the nineteenth century. How many little things dug out of the earth, such as hatchet and spear-heads, knives, pottery, and coins, supply the learned antiquary with the light which discloses the doings of our forefathers. Even the fair sex of ancient times are re-embodied and dressed before the mind's eye, and bedecked with rude ornaments; for are not their cists, or boxes, containing torques, armlets, and rings, dug out occasionally? and even in localities now represented by miles of peat-bog, there are discovered not only ancient British ornaments, but even paddles or oars which are of the same form as those used by the Welsh at the present day for their "coracles," or little wicker boats covered with hides. But what has all this to do with coal? Why, if brass ornaments, spear-heads, coins, &c., betray the ancient haunts of man, the numerous remains of plants and stems of trees, found in the coal and coal measures, surely betray the vegetable

origin of coal, and tell us in the plainest language that this mineral fuel is the remains of vast forests, and other large growths of innumerable plants, which have lived, died, and have been entombed by the all-merciful hand of Providence thousands of years ago, and are now being exhumed for our benefit, to give us health, in the shape of cheap warmth, and wealth more abundant than the imaginary contents of Aladdin's cave.

Fig. 2. Tropical Scene in Borneo.

The above illustration of a tropical scene in Borneo, the late home

of the illustrious Sir James Brooke, Rajah of Sarawak, will afford some idea of the exuberance of foliage prevailing commonly at the present time; and it is presented in order to indicate what the coal such as we have in England was not obtained from, and that we are not to suppose, as it was formerly imagined, that the plants and forest trees grew only in tropical climates, and were then transported by water-carriage to the more temperate parts of the globe; but rather that a peculiar condition of the atmosphere excited and maintained the wonderful life and activity in the vegetable kingdom which prevailed at the period of the formation of the coal measures, and that the forests grew at about or near the localities where the coal is deposited at the present day.

The once familiar "Drift" theory which accounted for the production of our British coal, supposed that vast forests were swept from the land into the arms of the mighty ocean or into vast lakes, by continual inundations or powerful streams, just as the trunks and branches of trees are swept from the banks of the river Jordan, and are carried into and

Fig. 3. The Dead Sea, from a Photograph by Negretti.

thrown up on the surface of the Dead Sea, to be again deposited, like gaunt skeletons, on its shores; or on a grander scale, as by the overwhelming volume of the vast rivers of the Mississippi or St. Lawrence, in North America, where thousands of trees float annually down the stream to the Atlantic, and are there deposited, with soil, sand, and clay, in process of time, in the bed of the ocean.

"The Drift Theory" receives a further elucidation in the next simple diagram of Professor Phillips. "Thus, at the point A in the next diagram, a series of limestone, sandstone, shales, coal, ironstone, occur, these being the common names of the rocks which are associated with coal. The limestone may be supposed to have been brought by diffusion in the ocean from an area situated to the south-east, the shale transported from the west, and the sandstone, plants, &c., drifted from the north. We may imagine two rivers, one flowing from the west, and

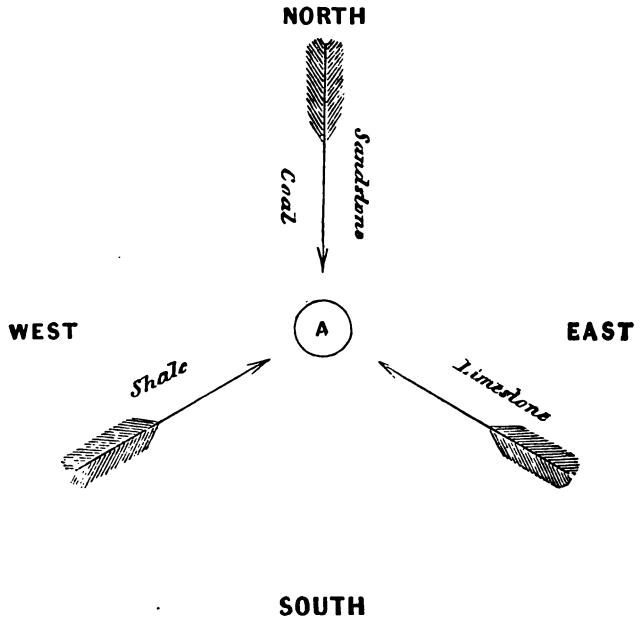


Fig. 4. Illustration of Drift Theory.

bringing across the regions where now are Ireland, Lancashire, Derbyshire, and South Yorkshire, a vast body of argillaceous (clayey) sediments, slightly charged with sand, and but little varied by floating trees and plants; the other rushing from the north, loaded with sandy matter, and bearing abundance of trees of different kinds, *but not many ferns or delicate herbaceous plants*. Alternately, or contemporaneously, these rivers might fill the sea with deposits such as we behold, and in the manner that we see them united with the proper calcareous deposit of the ocean." In appreciating the "drift theory," it must be remem-

bered that the "ancient ocean" is supposed to have been very different from the present one, and the arrangement of land and water quite dissimilar to the present order of these ancient elements. The Northern Ocean, at the commencement of the coal period, was, it is supposed, divided into basins, varied by islands, bounded by shores, supplied by inundations from extended land. One of the most interesting localities presenting an analogy to the dense island forests of the ancient coal period is one of a group of islands called the Great Andaman Islands, situated in the Bay of Bengal, and about one hundred and forty miles long and twenty broad. The extreme thickness of the tree jungles

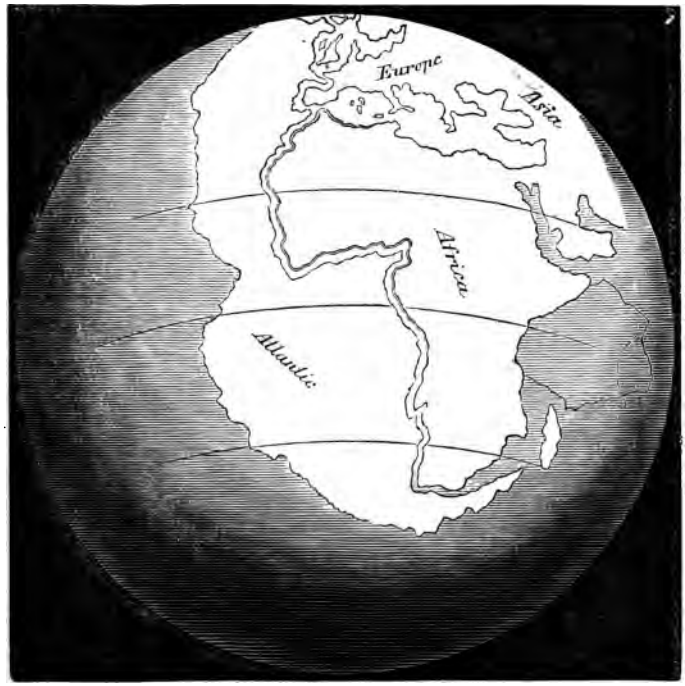


Fig. 5. The Earth before the Separation (Snider's Diagram).

which cover nine-tenths of this island, renders it almost impenetrable, they being composed of trees as straight as arrows, of from thirty to forty feet high, though their roots cannot expand much beyond one foot, and are found twisted together like so many coils of rope. The foliage

is confined to the tops of the trees, the trunks of which are leafless and branchless. The wood of the jungle trees is very hard, so that the axe flies off them as from stone. There seems to be no grass whatever, a great lack of water, and no rivers, but only brooks, which are dry in the summer and torrents in the rainy season. There are no wild animals except rats, snakes, and very little pigs, and all attempts to establish any intercourse with the aborigines have failed.

"The agitation of the shores of the Northern Ocean," says Phillips, "is proved by conglomerates (matter rolled like currant dumplings into balls); the amount of inundations from the land is demonstrated by an abundance of clayey and sandy sediments, plants, and beds of coal; while in the more tranquil laboratory of the deeper water, limestone rocks were generated in great abundance."

M. A. Snider, in a work entitled "La Création et ses Mystères dévoilés," gives two diagrams which are intended to show the alteration of the relative positions of land and water on the surface of the globe since its creation.

At this period (Fig. 5) M. Snider supposes the earth to have been one continuous block or mass rising out of the ocean, and the space marked the Atlantide (the Atlantic) to have been formerly dry land, but now changed to the bed of the mighty Atlantic Ocean. Sir Charles Lyell says, "It can be shown that the earth's surface has been remodelled again and again; mountain chains have been raised or sunk; valleys formed, filled up, and then re-excavated; sea and land have changed places; yet, throughout all these revolutions, and the consequent alterations of local and general climate, animal and vegetable life has been sustained.

"This has been accomplished without violation of the laws now governing the organic creation, by which limits are assigned to the variability of species. The succession of living beings appears to have been continued, not by the transmutation of species, but by the introduction into the earth from time to time of new plants and animals, and each assemblage of new species must have been admirably fitted for the new states of the globe as they arose, or they would not have increased and multiplied and endured for indefinite periods."

The eminent naturalist, Mr. Charles Darwin, in his work "On the Origin of Species by means of Natural Selection, or the Preservation of Favoured Races in the Struggle of Life," is opposed to the theory of the introduction of new species and new plants, and insists on the natural provocation to variety, and he says, "The more living beings can be supported on a given area, the more they diverge in structure, habits, and constitution; therefore, the more diversified the descendants of any one species become, the better will be their chance of succeeding in the battle of life. It is a truly wonderful fact—the wonder of which we are apt to overlook from familiarity—that all animals and all plants, throughout all time and space, should be related to each other, in group subordinate to group in the manner which we everywhere behold—namely, varieties of the same species most closely related together;

species of the same genus less closely and unequally related together, forming sections and sub-genera; species of distinct genera much less closely related; and genera related in different degrees, forming sub-families, families, orders, sub-classes, and classes. The usual subordinate groups in any class cannot be ranked in a single file, but seem rather to be clustered round points, and then round other points, and so on in almost endless cycles. On the view that each species has been independently created, I can see no explanation of this great fact in the

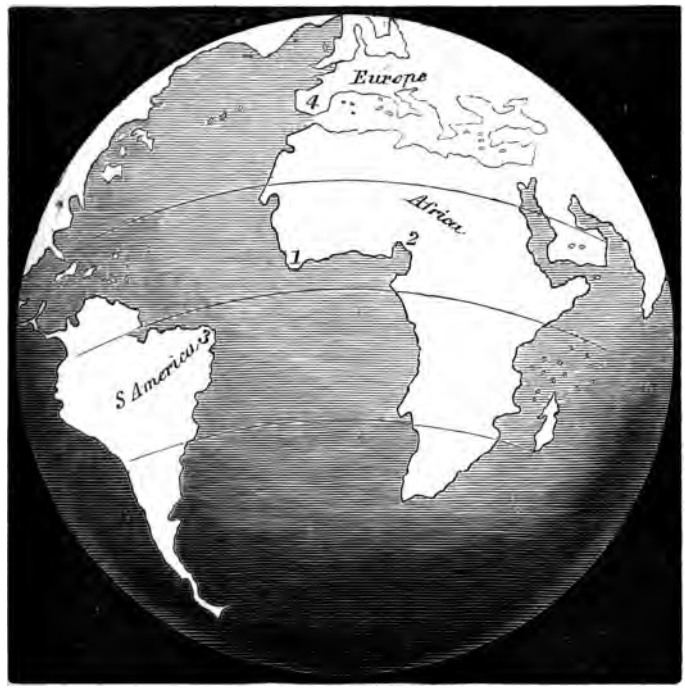


Fig. 6. Arrangement of the Land after the Separation (Snider's Diagram).

classification of all organic beings; but, to the best of my judgment, it is explained through inheritance and the complex action of natural selection, entailing extinction and divergence of character. . . . As all living forms of life are the lineal descendants of those which lived long before the Silurian epoch, we may feel certain that the ordinary succession by generation has never even been broken, and that no cataclysm [deluge] has desolated the *whole* world."

The second diagram (Fig. 6) represents the same terrestrial globe after the division of its parts at the surface, with the formation of the North and South Atlantic Ocean. The great uniformity of the fossil plants of the coal measures of Europe and North America is a convincing proof of the former existence of a continent or chain of islands where the Atlantic now rolls it waves. Four-fifths of the fossil coal plants collected in Nova Scotia have been identified with European species; and there are also other geological proofs of the existence of an ancient land situated to the eastward of the present Atlantic coast of North America. 500 B.C. Herodotus mentions fossil fishes as occurring in the rocks of Egypt, and states this as a proof of that country having been formerly an arm of the sea, like the Red Sea. Without advocating the truth of the first diagram, enough has been said to indicate some of the points of the "drift theory," by which it is attempted to explain the origin of coal.

The opponents of the "drift theory," it must be admitted, bring formidable arguments against it; and the following objections, arranged in a condensed form under seven heads, by the late Mr. G. F. Richardson, may not be uninteresting.

1. The purity of coal, and its freedom from extraneous substances. Had it been drifted, it must have acquired some portion of foreign substances in its transit, such as pebbles, gravel, &c.; but since we find extensive seams of coals unmixed with any other matters, its freedom from these is considered to be incompatible with the idea of its having been drifted from a distance.

2. The generally uniform thickness of each coal seam is considered to offer another difficulty. The lower main seam of the great northern coal field, according to Mr. Bowman, extends over at least two hundred square miles, while a thin seam is pointed out as reaching in a straight line from Whaley Bridge to Blackburn, a space of thirty-five miles. Had the coal been washed away by floods or torrents, such currents, either from the different specific gravity of portions of the same mass—of the roots and stems, for example, as contrasted with the branches and foliage—or from the mechanical destructions occurring in such a transit, would have deposited them in an unequal manner; whereas no such effects are discernible in the coal seams, which are invariably free from inequalities of this kind.

3. The exceeding minuteness of many of the coal seams, which thin out into mere filaments, and extend in this condition over extensive areas of solid rock, militates against the idea of any deposit of so attenuated a nature having been spread over spaces so large by the act of drifting.

4. On the other hand, the size of many of the coal seams considered with reference to the immense compression which they have unquestionably undergone, is considered to furnish another objection of insurmountable character. The enormous extent to which the bulk of substances may be reduced by pressure, can scarcely be imagined, except by a reference to exact computation. It was ascertained by Mr. Burr, that a mass of rubbish which was left in a worn-out vein of ironstone, during a period of ten

years, was in that interval reduced from seven to two feet in thickness, owing to the pressure of the overlying weight. It was further changed into so hard a substance as to form a mass of rock which could only be penetrated by the operation of blasting. When we consider the great compressibility of vegetable matter, and reflect that beds of coal have been subject to the pressure of masses of rock many thousand feet in thickness, during a period of countless ages, and when we recollect that matter so compressed has formed beds of great relative thickness, it is evident that, for the formation of such deposits, supplies on the most enormous scale would be required, and that it would be utterly impossible to transport masses of vegetable substances so immense as would be requisite for the formation of the coal deposit alone.

The effect of great pressure produced by Bramah's hydrostatic press is well illustrated in the compression of the bales of Manchester cotton goods, and of all kinds of paper, gunpowder in the stage of press cake, compressed trusses of hay, candle-making, seed-crushing and pressing, whilst the constant downward pressure of the superincumbent strata will be explained more fully afterwards in what are called "Creeps," when the earth, or floor, or metal of the excavated galleries in a coal pit gradually rises and fills the spaces left between the pillars of coal that support the roof.

5. The high state of preservation in which many of the plants occur, the perfect condition of the leaves and parts of fructification of many of the ferns, the sharp angles of numerous stems which are pronounced to have been of a soft and succulent nature, with the surfaces of *Sigillariæ* marked with lines, streaks, and flutings so delicate that the mere drifting of a day would have inevitably destroyed them. These, with other facts of a like nature, convince us that these plants have never been subjected to drift, *but were buried on the spots where they lived and died.*

6. An additional objection to the drift theory is founded on chemical facts; it has been urged, that if vegetable matter were swept away by a flood, such an agency, by allowing the gaseous elements to escape, would be inadequate to produce the desired results, and that coal never could be formed by such a process.

7. The multiplied instances of trees found erect, establish the fact of the coal plants having chiefly grown on the spot where they are now entombed.

Midway between the "drift" and "submergence" theories, it will be perhaps instructive to pause in order to mention a theory which has been urged with great power and ingenuity by Mr. Evan Hopkins, C.E. —viz., the actual movement of the crust or outer crystalline shell of the earth as it were in a spiral direction from the South to the North Pole; so that any given country like Great Britain shall, in process of time (to be numbered by thousands of years), have its position moved from a warm to a colder latitude by the mechanically-destructive and chemically-solvent power of water, aided by electro-chemical currents and crystallization, just as a plate of copper may be gradually dissolved at the positive pole of the battery, and again deposited at the negative pole to form an electrotype. Mr. Hopkins is entirely opposed to the Plutonic

theory, and warns his hearers not to look at the strata of the earth through "red spectacles," but to admit a little more "soda water" (having a cooler and quieter agency in this globe than fire) into their speculations as to the formation of rocks. The arguments most forcibly used in favour of the idea of a movement of the earth's surface from south to north by the electro-magnetic currents are: 1. The changes of latitude which have occurred in various recorded instances.* 2. The result of the change of latitude—viz., change of climate. Hence it is urged that formerly England was differently placed, and enjoyed a tropical or warmer climate; and during that period the coal-plants grew and expanded into those gigantic proportions which seem to be the speciality of the flora of the coal-measures. Could elephants live in Siberia at the present time? yet the remains of these warmth-loving animals are found in abundance there. Wines were formerly made of the grapes grown in the open fields of England; and it is stated that when Cæsar invaded Britain 1915 years ago, the site of the city of London was in latitude 40° 30′, and therefore in a climate corresponding to that of Portugal, which gives us our much-loved "Port;" whereas now we know that the latitude of Greenwich is 51° 28′ 38″.

The second theory that accounts for the production of coal may be called "*the Theory of Submergence*," in contradistinction to the other already discussed, called the *Drift Theory*.

It is assumed that there was a period in the history of our globe when a damp and steamy heat, with incessant rains and an atmosphere highly charged with carbonic-acid gas, prevailed on the surface of the earth. Then repeated storms, lightnings, and the fearful thunder broke only upon the solemn silence that prevailed; for, as Hugh Miller says, "no human being had yet left an imprint of his foot on the soil where the coal plants grew."

This damp and steamy heat our artist has endeavoured to portray in the next picture, where we see the sun vainly struggling to send his rays through the atmosphere highly saturated with vapour. Such an atmosphere may be partly realized by a visit to any gardener's forcing-house, and would of course be the means of increasing enormously the rank growth of the underwood and trees of the coal forests, whilst the continuous rains would wash down and dissolve out of the atmosphere the carbonic-acid gas, carrying it to the roots of the plants in that liquid state best adapted for its assimilation. If we could imagine a plant taking a breakfast, dinner, and tea, carbonic-acid gas, like our "daily bread," would always form a part of each meal. Then, again, the repeated storms and excess of demonstrative electricity, the continual flashes of lightning, no doubt produced soluble nitrogenous matter, such as nitric acid, which was in like manner supplied to those plants that required it for their sustenance.

Of the presence of the carbon (of the carbonic-acid gas) and the nitrogen (derived possibly from the nitric acid) in coal we have abun-

* Usually explained astronomically by the phenomenon called the "Precession of the Equinoxes."

dant evidence; and of the rain that undoubtedly fell at that period in such unusual quantities, there are the stony records in the rocks associated with coal. The sandstone and green shale, especially in those specimens collected by Mr. Brown from Cape Breton, Nova Scotia, bear upon their surfaces indubitable marks of rain-drops.

Fig. 7. The humid Atmosphere and rank Vegetation of the Coal Period.

The damp heat, the constant supplies of nutritive matter, brought about a gigantic condition of the plants and trees which reminds us of the huge root displays of modern horticultural shows, with their giant

beetroots, colossal turnips, carrots, &c. The effect of this stimulating action was to make the most humble plants spring up into forest trees; thus there were trees in the coal flora allied to the club-moss tribe, nothing but a tender bit of moss, and yet these plants shot up into

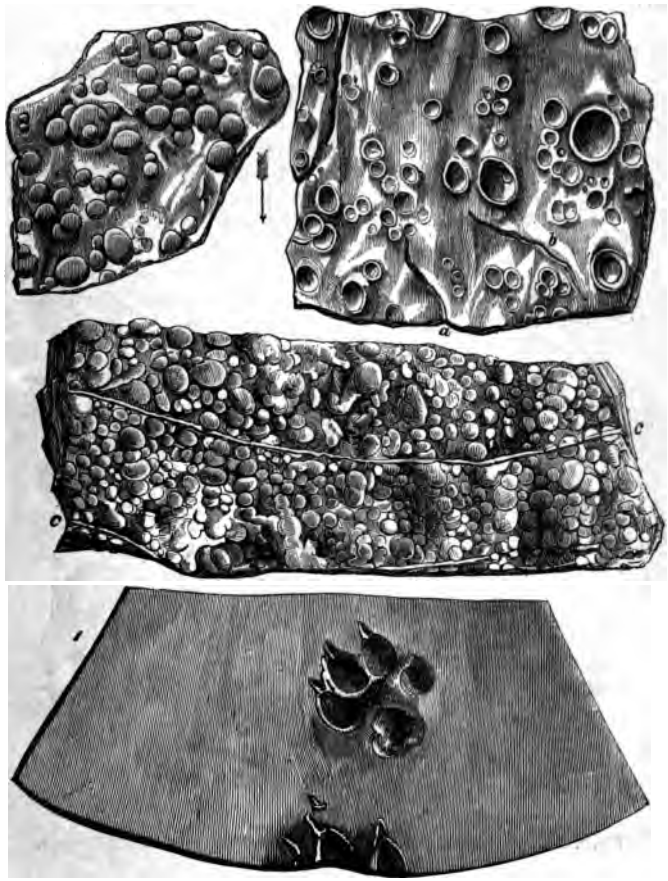


Fig. 8. Rain-prints and Worm-tracks (*a b*) from the upper and under surface of green shale rock from Cape Breton, Nova Scotia. *c c.* Shrinkage-cracks and Rain-prints on the under side of a layer of sandstone rock. *i.* Dog's Foot-print, made July 17th, 1850, on recent mud of the Bay of Fundy; removed by Sir Charles Lyell immediately after the impression was made, and showing how such records (as the rain-prints) may be left of past events. The latter copied from specimens in the possession of Professor Tennant, 149, Strand.

large trees from thirty to forty feet in height. It is interesting to know that the same wonderful activity of the vegetable kingdom is to be observed, to a great extent, in many forests at the present day, and especially in the West Indies; there, plants, which in our climate might be elegant creepers, such as the jasmine and clematis, fit to train on the

Fig. 9. Traveller in West Indian Forest; Accident from overhanging Creepers.

walls of a pretty cottage, grow up, under the effects of a West Indian climate, into great ropes and cables, which intertwine and hang from tree to tree, and must be carefully avoided in attempting to ride through these forests, or the incautious traveller may find himself suddenly entangled and lifted from his horse.

The great humidity of the climate of the coal period had been previously inferred from the nature of its vegetation and the continuity of its forests for hundreds of miles; but it is satisfactory to have at length obtained such positive proofs of showers of rain, the drops of which resembled in their average size those which now fall from the clouds. From such data we may presume that the atmosphere of the carboniferous period corresponded in density with that now investing the globe,

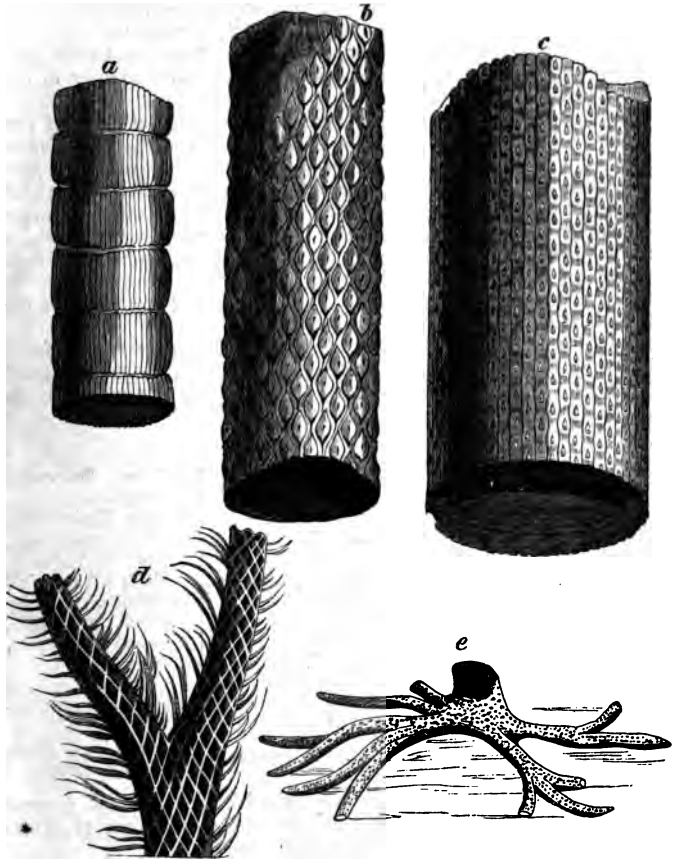


Fig. 10. Remains of Fossil Stems and Plants of the Coal Measures. *a*. A Calamite. *b*, *c*. Sigillariæ. *d*. Lepidodendron. *e*. Stigmariæ, root of the Sigillaria.

and that different currents of air varied then as now in temperature, so as to give rise, by their mixture, to the condensation of aqueous vapour. —Lyell's "Geology."

It might, however, be supposed that all statements with respect to the origin of coal must be imaginary, and partake only of the fascinating nature of fiction. No; the skeleton remains of plants which enable the botanist to revivify the dead forests of the carboniferous period are continually coming to light as the coal is dug from its rocky bed. In Fig. 10 we have ferns—calamites, bamboo-jointed—reed-like plants, *Lepidodendra*—and, more curious than all others, here are the sigillariæ, which scarcely present any analogy with existing forms, and must have imparted, as Miller says, "a strange and wondrous character to the flora of the coal measures."

The ferns appear to have been the most abundant, at least if our judgment in this respect is to be formed from the fossil specimens already obtained. There seems, however, very good reason to believe that we cannot make a just estimate of the exact proportion of one kind of plant, or of its superabundance as compared with others, because it would naturally happen that there might be a great difference in the capabilities of certain plants of resisting the action of water longer than others, and therefore our ideas of the precise state of the flora at the time of the growth of the great coal-producing vegetation of the forests must be somewhat obscure.

In order to assist the student of palæontology, or study of fossil plants and animals, it is advisable to keep the following table constantly in view, as it demonstrates the names of the groups of plants so often alluded to—

	Brongniart.	Lindley.	
Cryptogamic.	1. Cryptogamous Amphigens, or cellular Cryptogamia	Thallogens	Lichens, Sea-weeds, Fungi.
	2. Cryptogamous Acrogens... ...	Acrogens ...	Mosses, Equisetaceæ, Ferns, Lycopodiums, Lepidodendrons.
Phanerogamic.	3. Dicotyledonous Gymnosperms ...	Gymnogens ...	Conifers and Cycads.
	4. Dicotyledonous Angiosperms...	Exogens ...	Compositæ, Leguminosæ, Umbelliferæ, Cruciferæ, Heaths, &c. All native European trees except Conifers.
	5. Monocotyledons	Endogens...	Palms, Lilies, Aloes, Rushes, Grasses.

The term *cryptogamic* is of course derived from the Greek κρυπτος and γαμος, concealed fructification, and is applied to a class of plants whose stamens and pistils are not distinctly visible.

The *thallogens*, or flowerless plants, which have no proper stem or leaves, such as lichens, seaweeds, and fungi, are remarkable for certain

characteristics peculiar to all; they are entirely formed of cellular tissues, or rather of interlacing tubular filaments, without vessels properly so called; they never present true leaves, and their organs of reproduction consist only of very fine seedlings, which appear to de-

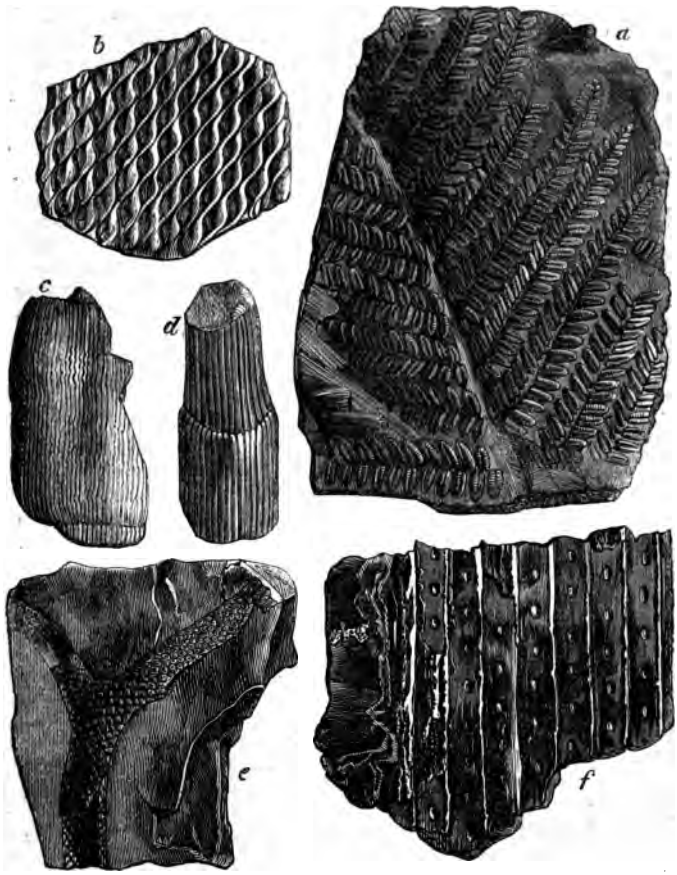


Fig. 11. *a.* Pecopteris. *b.* Lepidodendron. *c, d.* Calamites. *e.* Lepidodendron. *f.* Sigillaria. All drawings of fossils in Professor Tennant's Collection.

velope themselves without fecundation, and are immediately enclosed in membranous conceptacles analogous to the filaments of that tissue

which composes the whole of the plant. The only fossil plants of this class known are some *confervæ* with several *algæ*, or seaweeds.

The second class comprises cellular cryptogamiæ, or mosses, which present in their general form and structure features similar to those of the most perfect vegetables; in this class are also grouped the Equisetaceæ, Ferns, Lycopodium, Lepidodendrons, which possess more varied tissues, and include perfectly distinct vessels, and very frequently spiral vessels, or imperfect spiral vessels, while the leaves are in general very fully developed and furnished with cortical pores. The stems, often large and arborescent (Figs. 10 and 11), have some analogy with those of Monocotyledons, or plants having one seed-lobe. M. Adolphe Brongniart has called the period of the formation of the coal measures *the age of Acrogens*, in consequence of the vast preponderance of ferns, and Lepidodendra, and the apparent absence of Exogens, or ordinary Dicotyledons, or plants having two seed-lobes; nevertheless, Lyell supposes a forest of that period may have borne a considerable resemblance to those woody regions of New Zealand, in which flourished ferns, arborescent and herbaceous, and lycopodiums, with many coniferæ, or pine-trees, probably similar to the *Wellingtonia gigantea*, depicted at page 3, the bark of which is deposited and built up in the north transept of the Crystal Palace, Sydenham. With reference to this gigantic specimen, Lord Richard Grosvenor, in a letter dated November 3rd, 1859, and addressed from San Francisco, California, says:—

"I have just been on a trip into the interior of this State to see the 'big trees,' and they are worth coming here to see. Imagine a tree 116 feet in circumference, and 450 feet high! There are several groves of them, all on the western slope of the Sierra Nevada, and all about the altitude of 4000 feet above the level of the sea. I have been to see two of them: one in Calaveras county, and the other grove in Mariposa, both about 200 miles from here, and the latter in a south-westerly direction. They are beautiful trees, but I do not think the branches are large enough in proportion to the trunk; they are, in fact, very small, and hang down in a nearly perpendicular fashion, sometimes bending down in a semicircular arch, so as to touch the trunk again, which makes them rather look like very tall masts. The trunk is beautifully proportioned, and tapers off to a fine point, so you do not appreciate the height till you find you have sprained your neck in trying to see the top. *The bark* is a pretty yellowish cinnamon colour, of a very fine texture, often twenty-two inches thick; but that you have seen at the *Crystal Palace. The tree from which that bark was taken is still standing, with the scaffolding round it which was used on the occasion.*"

The Phanerogamic group includes those plants which have visible flowers containing stamens and pistils.

The most remarkable plants or trees belonging to the coal period were undoubtedly the Sigillariæ, with their vast roots called stigmariæ, of which about thirty-five species are known; and such was their individual abundance, that there are great seams of coal almost entirely composed of them. These "trees were interesting," as Miller says, "on

account of their beautiful sculptured stems, various in their pattern according to their species." All were fluted vertically, somewhat like columns of the Grecian Doric, and each flute or channel had its line of

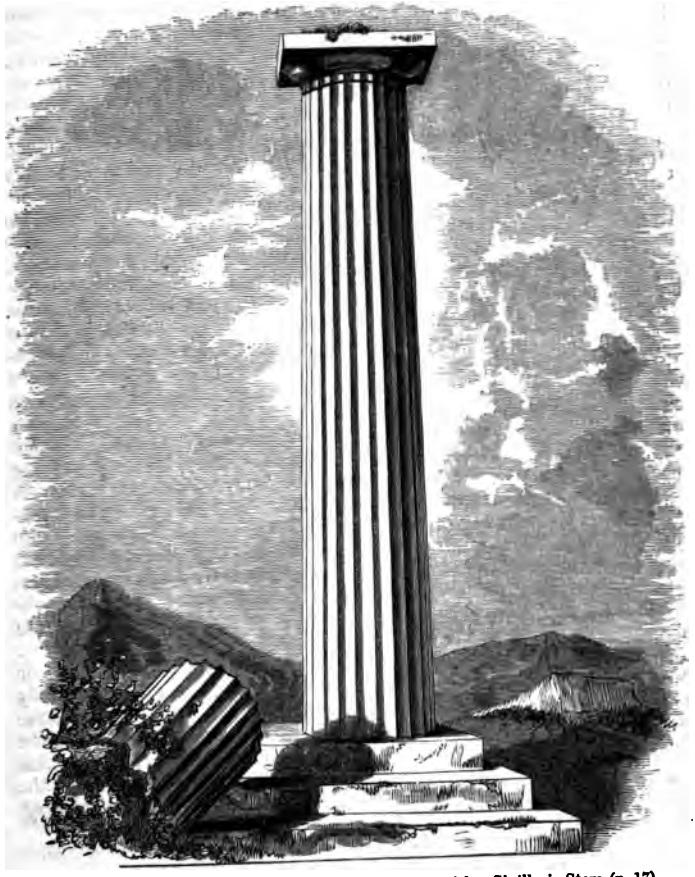


Fig. 12. A Grecian Doric Column, for Comparison with a Sigillaria Stem (p. 17).

sculpture running adown its centre, as we may notice in Fig. c, p. 17. . . . . "In walking amongst the ruins of this ancient flora, the palæontologist almost feels as if he had got among the broken fragments of

Italian palaces erected long ages ago, when the architecture of Rome was most ornate, and every moulding was roughened with ornament; and in attempting to call up in fancy the old carboniferous forests, he has to dwell on this peculiar feature as one of the most prominent, and to see, in the multitude of trunks darkened above by clouds of foliage, that rise upon him in the prospect, the slim columns of an elder Alhambra roughened with arabesque tracery and exquisite filigree work."

Having thus briefly attempted to give some idea of the flora of the dark and tangled forests of the coal period, our thoughts must be again directed to the process by which these tall tree-ferns, huge pines, reed-like calamites, sculptured sigillariæ, and hairy lepidodendrons were *submerged*, decomposed, condensed, and hidden for ages beneath the surface of the earth.

It is a subject of everyday observation to those who delight in country walks amid field and common, copse and wood, that wherever due regard is not paid to the all-important first principle of agriculture, viz., *drainage*—wherever water is allowed to accumulate, the soil, by being constantly saturated with moisture, is no longer able to admit the health-giving atmosphere, and in process of time the useful vegetation dies away, sinks down into and is decomposed in the morass, being succeeded by a rank and sour crop, which even the much-despised donkey will not condescend to touch. In a somewhat similar manner, though gigantic in degree, it has been assumed that water gradually invaded the vast forests, and saturating the earth, filled up all the pores and excluded the air, and from the circumstance of carbonate of iron being a constant companion of the coal seams, it may be imagined that the falling leaves and the tangled underwood, rotting in the watery bed, converted the peroxide or red oxide of iron in the soil (which is a valuable ingredient of the earth that supplies the healthy plants with food) into poisonous protoxide or green oxide, and directly this mineral poison began to act upon the forest trees they gradually died, and were submerged by the reception at intervals of deposits of silt and mud, the detritus of neighbouring and higher land.*

When the forest grew on the banks of broad and shallow lagoons or vast lakes the water would teem with vegetation, and might gradually supply materials for beds of peat. These lagoons, covering, perhaps, miles of country, by repeated sinkings may have subsided gradually beneath the level of the sea, and have rendered the basin the receptacle

* We are indebted to Kremer for careful analyses of the ashes of coal, of which we give an example, the per-centage of ash in the coal being 1·99, and its composition as follows:—

Silica	15·48
Alumina	5·23
Peroxide of iron	74·02
Lime	2·26
Magnesia	0·26
Potash	0·53
Soda	—
Sulphate of lime	2·17
	100·00

of alternating deposits of sand and clay, and may thus have produced the strata of sandstone and limestone which occur between the seams of coal. Such ideas respecting the inroads of the sea are supported by facts that are apparent at the present day—as, for instance, the remarkable rising of the tide in the Bay of Fundy, which is a large inlet of the Atlantic Ocean, and situated on the east coast of North America; the bay, separating the south part of the peninsula of Nova Scotia from New Brunswick, extending about 100 miles, with an average breadth of about 30 miles.

The tides in this bay frequently rise to the great height of 60 feet, and are, as may be supposed, very destructive; they sweep away the whole face of the cliffs, and thus a new crop of erect trees springs up about every three or four years. Rogers imagines that the areas now covered with the coal formation have possessed a physical geography, of which the principal feature was the existence of extensive flats bordering a continent, and forming the shores of an ocean, or some vast bay, and that this low coast was fringed by great marshy tracts or peat bogs, on which along the landward margin grew the *coniferæ*, tree-ferns, *lycopodiaceæ*, and other arborescent plants. If the fossils discovered in the coal measures were all of freshwater origin, the supposed effects of the sea would be purely imaginary; but there is abundant evidence of the mixed nature of the fossil remains, and of the association of fresh or brackish water with marine strata, not only in American, but also in the English coal fields. In the lower coal seams of Colebrookdale, in Shropshire (celebrated as the locality where railroads formed of wood were first used in the year 1620 and 1650, and about 100 years afterwards plated with iron), Mr. Prestwich suggests that the intermixture of beds containing freshwater shells, with others full of marine remains, and the alternation of coarse sandstones and conglomerate with beds of fire-clay, or shale, containing the remains of plants, may be explained by supposing the deposit of Colebrookdale to have originated in a bay of the sea or estuary, into which flowed a considerable river subject to occasional "*freshes*," or the mingling of fresh with salt water.

In the Edinburgh, Shropshire, and Staffordshire coal fields, also in those of South Wales and Somersetshire, the marine deposits are more or less associated with those of freshwater origin. Some geologists, and especially E. de Beaumont, have assumed, in order to account for the frequent alternation of coal seams and sedimentary rocks with marine products, a continuous sinking of islands, so that each coal seam was covered with sediment up to the level of the sea, and a new flora afterwards grew there, which was in its turn sunk below the water, and so on.

With respect to the production of the poisonous protoxide of iron, and its effect upon the forests of the coal period, it is interesting to know that Professor Hunt, of the Museum of Practical Geology, has instituted a series of experiments, to illustrate the production of clay ironstone, bands and nodules of which are so common in the coal measures; and he has found that decomposing vegetable matter (such as

would be distributed through all the coal seams) prevents the further oxidation of the proto-salts of iron, and converts the peroxide into protoxide, by taking a portion of its oxygen to form carbonic acid gas. This gas coming in contact with the protoxide of iron in solution, would unite with it and form a carbonate of the protoxide of iron, and mingling with the excess of fine mud, might form beds or nodules of argillaceous or clay ironstone. When pure, carbonate of iron is composed of

Protoxide of iron	61·37
Carbonic acid	38·63
	100·00

The carbonate of iron ore occurs in flattened nodules in connexion with the coal at St. Etienne, a locality we shall again allude to, and is composed of

Carbonic acid	38·4
Protoxide of iron	41·8
„ „ manganese	4·1
Lime	0·2
Magnesia	0·3
Silica	12·3
Alumina	3·2
	100·3

Speaking again of the inroads of water, there is a very interesting example of the effects of such natural causes in the marsh lands which once formed an estuary or arm of the Bristol Channel, and the formation of extensive peat bogs on what are provincially termed the *Turbaries*. The levels are about two hundred square miles in extent, and at the present time a great part of those flats are below the level of the spring tides, but barriers formed by nature and improved by art keep back the sea. In ancient times the low lands became a morass or lake of fresh water, and in such situations commenced the formation of peat. The changes are interesting, and afford a good notion of the probable formation of many coal seams; and they are thus described by an eye-witness, who writes so pleasingly in "Chambers' Journal." He says:—

"First, the reeds spring up, because they can raise themselves out of the water; then other aquatic plants help themselves up by the stalks of the reeds, till at length the confervæ thicken the mass so much that the surface becomes suitable to the sphagnum tribe, to which succeed lichens, rushes, and grasses. This spongy mass of vegetation consolidates, sinks below the surface, falls to the bottom, and there decays, receiving year by year a fresh accumulation. This decomposed matter becomes a semi-fluid and dark-coloured substance, which undergoes fermentation, hence the bituminous and inflammable properties of peat, into which this homogeneous mass is now converted. In this process nature requires that the water should be quiescent, for should any current disturb the stagnant morass, it would carry off the astringent

juice, which is the chemical agent for turning the decomposed vegetable mass into peat. The '*moss water*,' as it is called, is highly antiseptic, and of so astringent a nature, that an attempt was made some years ago to apply it to tannery purposes. The thickness of this congeries of plants is from fifteen to eighteen feet; it is kept buoyant by the water in the basin, and assisted, no doubt, by the clinging bubbles of gas derived from its partial decomposition. In winter, the peat rises so much above the level of the surrounding land, that people who live on the borders of the turbaries cannot see objects which are clearly discernible in summer."

The State of Michigan, in America, is remarkable for the abundance and value of its peat deposits. In this locality the peat beds are more condensed and compact, being comparatively shallow, and seldom exceeding four feet in thickness. It most commonly overlies beds of calcareous marl, which has accumulated in the innumerable low meadows, beaver swamps, and wet prairies of the country. Michigan has been aptly designated by the Indians as "The Land of Lakes;" and a professional geologist has reported on the existence of not less than *three thousand lakes* within the limits of the peninsula. The condition of a vast territory, like that of the new States of America, thinly peopled, and with its swampy lakes undrained, supplies a good illustration of the probable condition of thousands of miles of the surface of the earth when the flora of the coal measures attained their gigantic proportions. It is stated that peat taken from land which has been many years *drained*, when dried, *is nearly as heavy as oak wood, and bears about the same price* in the market of Rhode Island, where peat abounds.

In the more ancient periods, after the peat was formed in the moist state, accidental drainage, from alteration of the levels, might occur, with its gradual submergence and condensation; and so, in the course of hundreds of years, coal would be produced. The analysis of New Hampshire peat by Messrs. Whitney and Williams is as follows:—

Locality.	Vegetable matter.	Silica, alumina, iron, and lime.
Meredith	94·90	..... 5·10
Canterbury	93·80	..... 6·20
Franconia	73·70	..... 26·03

Baron Liebig considers that wood, or brown coal and mineral coal are the remains of vegetables of a former world, and that they are the results of decompositions termed *decay* and *putrefaction*. Woody fibre and linen both contain a proximate principle termed *lignin*, so that there is a great connexion between the two, so far as their chemical composition is concerned. When heaps of rags are moistened with water they become warm, carbonic-acid gas is evolved, and their weight diminishes from eighteen to twenty-five per cent., and the rags are converted into a soft, friable mass, which has lost its coherence. When sawdust is moistened with water, it also evolves considerable heat, which in the presence of other combustible matter has even increased until flames have burst forth from the mass. The author recollects a

case of this kind, where the contents of an underground dustbin, which had been nearly filled with sawdust, took fire spontaneously, and where the whole mass of sawdust was found to be blackened, and caked together into a porous coal-like mass. Pressure and temperature have greatly affected the decomposition of the ancient submerged vegetation. A piece of wood, which had been placed in the boiler of a high-pressure steam engine, and subjected to a temperature of between 334° and 352° Fahr., with the corresponding pressure of between seven and a half and nine atmospheres, was found to be converted into a species of coal, which had precisely the same composition as Laubacher coal.

A piece of wood swallowed by a pig and retained in the stomach, causing its death, was examined by the author, and had very much the appearance of petrified wood. Decomposition of coal is continually going on, and gases eliminated from it. In the vicinity of a layer of wood coal in Germany the springs of water are usually found to be highly charged with carbonic acid. The wood coal by analysis is found to contain the exact elements of woody fibre or lignin minus a certain quantity of carbonic acid. The gases formed in mines of wood coal, causing danger in their working, are not combustible or inflammable as in mines of mineral coal, but they consist generally of carbonic acid gas, and are very seldom intermixed with combustible gases. The combustible hydrocarbon called carburetted hydrogen, generally accompanies all mineral coal, and is usually found mixed with nitrogen gas, carbonic acid gas, and sometimes olefiant gas, being called "fire damp." The constant evolution of these gases from coal in coal mines, proves that changes are always proceeding in the coal; and Liebig adds: "It is obvious that a continual removal of oxygen in the form of carbonic acid is effected from layers of wood coal, in consequence of which the wood must approach gradually to the composition of mineral coal." This, however, Bischof denies, and states that in no case can carbonic acid exhalation originate from brown coal: he further says, at every part of the earth where observations have been made, the temperature increases with the depth below the surface. If this same increase goes on at depths which are inaccessible, there must be a red heat at a certain depth. If at this depth there are beds of carbonate of lime, carbonic acid would be disengaged from them in the same way as in limekilns. Hydrogen, on the contrary, is disengaged from the constituents of mineral coal in the form of a compound of carbo-hydrogen; a complete removal of all the hydrogen would convert coal into anthracite. According to Liebig's view, the conversion of ligneous fibre into coal consists in the separation of certain quantities of its elements in the orm of oils, marsh gas, and carbonic acid.

When from the formula representing the composition of wood there are deducted three equivalents of marsh gas (carburetted hydrogen), three equivalents of water, and nine equivalents of carbonic acid, there remain the constituents of the splint coal of Newcastle and the canne coal of Lancashire.

One of the most interesting statements with respect to coal deposits

is that made regarding the "clay floor" which generally accompanies and forms the base on which the fuel rests. If an artificial pond or lake is to be formed, the porous nature of the soil in which it may be dug must be changed by lining the whole of the excavation with clay. How natural, then, that water accumulations which helped to destroy the ancient forests should take place on a clay base. Lyell says that "in South Wales the coal measures have been ascertained by actual measurement to attain the extraordinary thickness of 12,000 feet, the beds throughout, with the exception of the coal itself, appearing to have been formed in water of moderate depth, during a slow, but perhaps intermittent depression of the ground, in a region to which rivers were bringing a never-failing supply of muddy sediment and sand. The horizontal extent of some seams of coal is much greater than that of others, but they all present one characteristic feature in having each of them what is called *underclay*. These underclays, co-extensive with every layer of coal, consist of arenaceous (sandy) shale, sometimes called firestone, because it can be made into bricks which stand the fire of a furnace; they vary in thickness from six inches to more than ten feet; and Mr. Logan was the first to announce to the scientific world, in 1841, that they were regarded by the colliers in South Wales as an essential accompaniment of each of the one hundred seams of coal met with in their coal fields. They are said to form the floor on which the coal rests; and some of them have a slight admixture of carbonaceous matter, while others are quite blackened by it. What a commentary on drainage is here supplied; the sturdiest forest trees sunk down into decay when the water accumulated at their roots, how much more, then, delicate plants, such as grasses, cereals, and other crops in the agriculture of man. Another curious circumstance is that all the "floors" are characterized by enclosing a peculiar fossil vegetable deposit called "Stigmariæ;" the latter was formerly supposed to be an aquatic floating plant, but is now ascertained to be the *root* of the sculptured Sigillaria. It was also observed that while in the strata lying on the coal or the roof of the coal, ferns and trunks of trees abound without the stigmariæ or *roots*, and are flattened and compressed, the latter in the underclays always retain their natural forms, branching freely, and sending out their rootlets through the mud in all directions. With the "stigmariæ" we arrive, as it were, at the very base or foundation of coal, and our ideas of the truth of the "Submergence Theory" receive a fresh impulse when we grasp these important facts, described by Mr. Logan, which are supported by other and similar geological strata.

If all our coal was not worked in the dark and under the surface of the earth, a great many interesting fossil remains would come to light, and much information be gained on this important subject; occasionally, however, the coal does outcrop or come to the surface, and then being quarried out, with the adjoining rocks, like stone, presents the appearance indicated in our next picture, which is that of the celebrated coal mine of Treuil at St. Etienne, in the department of the Loire, in France. Here

the coal occurs in beds, which are evidently horizontal, and tracing up the strata from the level of the feet of the figures in the lower part of the picture, we have first coal five feet thick, then a bed of siliceous shale, then a layer of carbonate of iron ore in flattened nodules, and, ascending the path to the right, we have at the summit several thin seams of coal, more shale, more iron ore, and, finally, a bed of micaceous sandstone from eleven to thirteen feet in thickness, traversed by vertical trunks of monocotyledonous vegetables resembling branches or large Equisetaceæ, as it were petrified in the very places where they formerly stood as living trees.

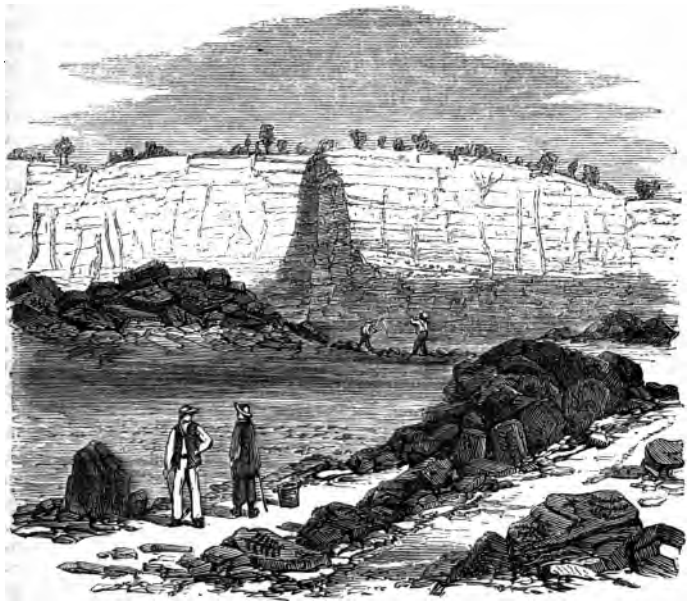


Fig. 13. The Coal Mine of Treuil, at St. Etienne, in the Department of the Loire, France.

Mark Brongniart, in his account written in 1821, very properly inferred that these fossil trunks were the monuments of a veritable *submerged* forest; and although Lyell at first objected to this conclusion, in consequence of the absence of roots, which he asserted ought to have been found at one and the same level, and not scattered irregularly through the mass, he has since withdrawn these objections, and has now little doubt, from his observation of similar remains near Picton, in Nova Scotia, that Brongniart's view is correct. These plants flourished in a sandy soil, no doubt liable to be flooded at various periods, and elevated by fresh accession of sediment, as may happen in swamps near the banks

of a large river in its delta.* Trees which delight in marshy ground are not injured by being buried several feet deep at their base, and other trees are continually rising up from new soils, several feet above the level of the original foundation of the morass; and in the banks of the Mississippi are to be seen sections of a similar deposit.

Conversion into coal is not the only change to which vegetable substances are subject. The substances of some organic bodies may be replaced by mineral matter in the same way that one mineral is replaced by another. Petrifaction is a change of this nature, and the fossil trunks of the Treuil coal mines, as in other localities, have long had their vegetable matter replaced by sandstone. Göppert, on treating silicified wood with moderately strong hydrofluoric acid, obtained a ligneous residue, which for the most part indicated the species of that wood; also on treating a fossil root, "stigmaria fucoides," fossilized by carbonate of lime, with diluted hydrochloric acid, the calcareous matter was dissolved away, and there remained a residue presenting the entire structure of the root in its natural arrangement and colour.

Bischoff says, "Silicification is a phenomenon so common, that it is not necessary to assume the existence of any peculiar circumstances during the petrification of stems of trees in the coal formation, which, when standing erect, are but little crushed, and very much so when lying horizontally. This petrifying material is either in an earthy or a hard state, coarse or fine-grained. In the latter case, the minutest ligneous fibres can be recognised. In the silicified trees of the coal formation, which are mostly contained in the sandstone strata, the periphery consists of a siliceous, and the bark of a thin carbonaceous mass, while the interior is filled with sandstone. This siliceous mass is undoubtedly *a chemical deposit from the silica dissolved in sea-water*, and the sandstone a mechanical one, like the rock in which the trees are embedded. The analysis of the former does not show the presence of more than a mere trace of organic matter. Silica, indeed, appears to have a great affinity for organic matter, whether in animal or vegetable fossil remains, and is invariably a constituent of them." Mr. Evan Hopkins, who has travelled nearly all over the world, states "that there are immense siliceous and calcareous stumps in their natural growing position in Chili, Veraquas, in Australia, and Egypt; showing most distinctly that the trees became silicified, *when in the act of growing*, by an excess of silica or lime getting into the soil (like the trees of the Andaman Islands, which turn the edges of the axes like stone). The upper part having decayed, the whole forest appears to have been snapped off by the winds, and nearly at the same time, reminding us again of the fossil stumps of trees already alluded to.

Although the Treuil coal-mine has been quoted as a good example of the presence of a fossil forest, we are not confined to foreign countries for other examples. Hawkshaw describes five fossil trees exposed in a cutting on the Manchester and Bolton Railway, standing erect in relation to a bed of coal, and with their roots in a corresponding

* So called from the usual triangular shape of the land included between the channels of the river being similar to the Greek letter Δ, *delta*.

position. Another tree has subsequently been discovered on the opposite side of the railway, making the entire number six.

Fig. 14. Fossil Trees discovered in making one of the Railway Cuttings between Manchester and Bolton.

A section of the strata affords the following list of arenaceous and argillaceous deposits:—

1. Sand intermixed with patches of loam.
2. An intermixture of argillaceous and siliceous shales.
3. Siliceous shale.
4. A vein of coal ten feet thick.
5. Blue and white argillaceous shale, in which the trees are embedded.

The trees, when dug out, had each a coating of very brittle and friable coal, which crumbled away as the fossil trunks and roots were removed from the shale. The largest was about fifteen feet in circumference at its base, seven feet and a half at its top, and eleven feet in height; the others were from six to seven feet in circumference, and from two to five feet in height.

At the celebrated Craigleith quarry, near Edinburgh, there used to

be standing one or two enormous fossil trees, of the Araucarian division of the coniferous family, one of which, exposed in a slanting direction, was sixty feet long, having a diameter of five feet at the base, and gradually tapering off to a diameter of seven inches at the top. The bark was converted, like the specimens discovered on the Bolton and Manchester line, into a thin coating of the purest and finest coal, the fossil trunk was deposited in white quartzose sandstone, and the tree could not have been hollow when embedded, for the interior still preserved the woody texture in a perfect state, the petrifying matter being chiefly carbonate of lime with oxide of iron and alumina.

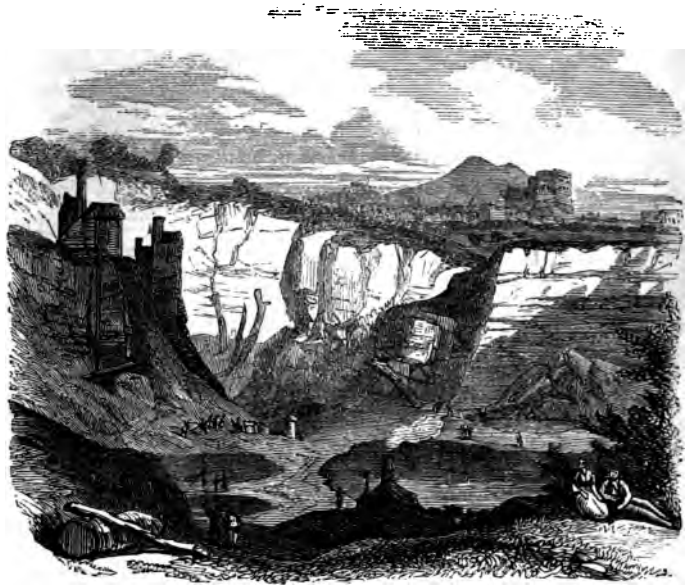


Fig. 15. Craigleith Quarry.

The geologist, in observing these and other fossil remains, can only come to the conclusion that fossil trees have originated partly from *submerged* forests and partly from *floating drift-wood*.

The colliers who work the coal, as it may be imagined, do not dignify these vegetable remains with the names of "fossil trees," but simply call them "coal-pipes." Of all things in the world, the miner delights in a tobacco-pipe, but he has an equal detestation of a "coal-pipe," and the reason of this dislike is soon understood. These great fossil

stone-converted trunks are usually conical—viz., larger at the bottom than at the top, and they are, as already observed, enclosed with a thin layer of coal, formed, seemingly, from the conversion of the bark into that mineral fuel; they have no branches, they stand erect, or nearly so, and the bond of union or cohesion between the bark and the surrounding strata is exceedingly slight; when, therefore, this is broken, either by the vibration of the coal-trucks or rolleys, or by an explosion of gunpowder in another part of the mine, down falls the ponderous and stony tree, and of course whatever living thing happens to be beneath it is either seriously maimed or killed.

Fig. 16. Accident by the falling of a Coal-pipe.

Such accidents sometimes happen at the Durham and Newcastle pits, and of course if they were laid bare and worked as quarries, all these fossil stumps would be observed, and danger prevented. It appears that the coal worked in Siam chiefly outcrops, or comes to the surface; and when the Siamese ambassadors visited England, one of their chief inquiries referred to coal-pits, and they could hardly be made to understand that in England men worked in the dark and underground for the purpose of procuring it.

And now we may ask, how long ago is it supposed that the coal was deposited? or, in briefer language, what is the age of coal? A precise

answer to this question would be impossible, or if attempted, could result only in vain and useless words. Bischof remarks that "Experience shows that coal, whether it has been formed by ordinary carbonization of wood or by the action of water, is one of the most indestructible of known substances. About ninety years since, pointed piles were found in the Thames at the place where, according to Tacitus, the Ancient Britons had driven in a great number of such piles, in order to hinder the passage of the river by Julius Cæsar and his army. They were all carbonized to a considerable depth, had preserved their form perfectly, and were so hard in the interior, that *knife-blades* could be made of them. As there is no chemical analysis of these piles, it cannot be decided whether they were merely carbonized or more or less petrified. If the vegetable remains under water or buried between rocks were capable of being completely destroyed, we should not anywhere meet with coal, *the age of which must be calculated by millions instead of thousands of years.*

The talented author of "Our Coal and Coal-fields," in speaking of a visit to a coal-mine, says: "You are in the catacombs of vegetable giants, you are treading the streets of more than a buried city of men and monuments. No storied arches are these, no marble busts are breathing a stony life here, no illegible descriptions are standing and lying here, no mouldering bones, no shrivelled mummies, no Egyptian cats, no dried ibis are here—no spoils of rapine, no relics of royalty, no fragments of luxurious appliances are here. . . . . Why, all around you are the relics of innumerable forms of vegetation which flourished and waved largely and luxuriantly in the warm breezes long before Egypt was dreamt of, or Nineveh even knew Nimrod, or Athens knew Theseus or Athene, or Rome knew Romulus, or to begin aright, Adam saw Eve. Every tree and plant whose ruins are here compressed into these beds of coal was ante-paradisiacal—was green and was wood centuries upon centuries before Eden had her first rose, and Eve her first walk amidst admired and admiring flowers! The age of the Pyramid of Ghizeh is nothing to this great pyramid of coal. Long, long before the first stone of that pyramid rose above the sand, these seams of coal were packed up close, arranged and ready for human discovery and use. The Pharaohs were great men, but the Pembertons, the diggers of the deep Monk Wearmouth shaft, are greater." And we might add the name of Astley, the digger of the deepest coal-pit in the United Kingdom.

The Pharaohs no doubt in their day were great kings, but they only built a mountain of stone to cover a molehill of royal dust; whilst the zealous and enterprising men, the diggers of coal-shafts, working for the just reward of their labours, have at the same time greatly benefited mankind by the fruit of their great works. Speaking of ancient mechanical appliances as compared with those of the moderns, who work with steam generated by burning coal, it has been calculated that the largest pyramid of Egypt, which is 500 feet high and 700 feet square at the base, might have been built and all the stone raised by

steam-power, with a consumption of about 712 tons of coal, as the great Watt has demonstrated that fifteen million pounds weight can be lifted one foot high by the consumption of one bushel of coal.

With this glance at the probable age of coal, we return again to the geological strata, for the purpose of learning how the coal reposes in its earthy bed, and whether it is found in horizontal, inclined, curved, or basin-shaped formations.

Here we come to the simple enunciation of facts, the previous pages

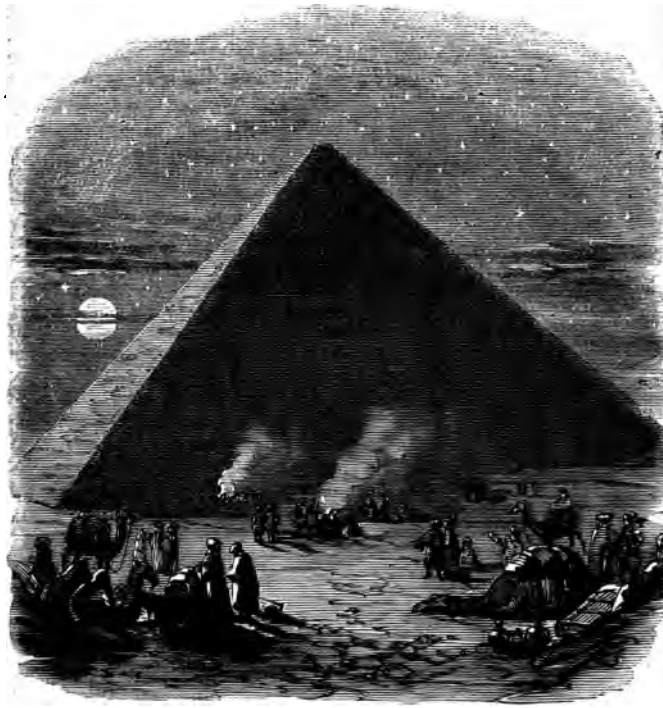


Fig. 17. The Pyramid of Ghizeh.

having been devoted largely to the consideration of the relative merits of the "*Drift*" and "*Submergence*" theories, which account for the origin of coal; but now it is necessary to deal with facts that are open to

the critical examination of all, and about which no doubt can possibly exist.

The coal strata were originally deposited in horizontal or nearly horizontal positions. But great changes have taken place in the rocks which compose the outer covering of the globe; and in order to give instruction in this most important department of geological science, Mr. T. Sopwith has constructed a series of correct models, presenting a facsimile of the succession of coal-seams in the Newcastle coal-fields, &c., &c., and affording a much better notion of geological phenomena than ordinary plans and sections. These beautiful models are sold in cases, bound and lettered to resemble books, by Mr. J. Tennant, geologist, 149, Strand.

By continual observation it has been discovered that all or nearly all the coal formations are basin-shaped, with long and sloping sides dipping

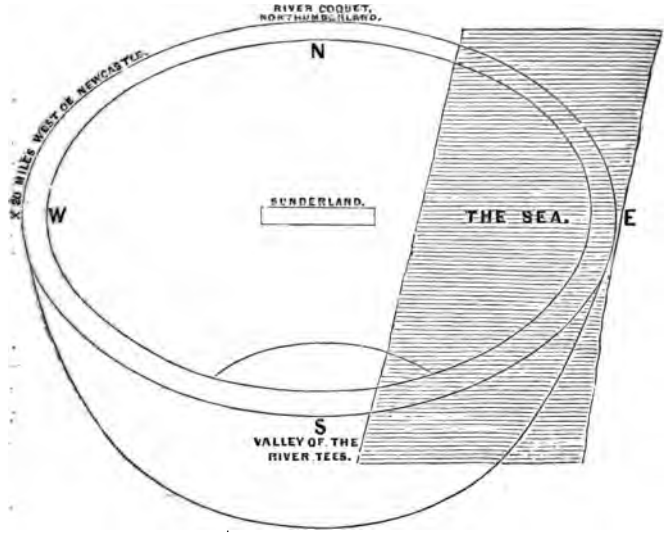


Fig. 18. The Great Coal Basin in the N.E. Corner of England.

down to a common and profound centre. This hollow or basin-like form is of so great an extent that an area of a few miles is not sufficient to exhibit it, just as the spherical or round form of the earth cannot be discovered by the examination of a few miles of country; hence, in Mr. Sopwith's No. II. model, representing a small area, the coal strata are

aptly represented, as regards the limited extent included, by a perfectly plane surface. To obtain a better notion of the basin-shaped arrangement of coal, the great and principal coal field in the north-east corner of Great Britain may be taken as an example, where the centre or bottom of the basin lies about Sunderland.

Taking a common washhand-basin (Fig. 18) for an example, and at the same time, stating that it should be rather *oval* than round, we may write in the centre, Sunderland, or place a piece of stick in the centre of the basin, with a label at the top, bearing the word Sunderland; and here, it may be mentioned, that the deepest coal pits of that region occur. The strata rise like the sides of a basin till they "crop out," or come to the surface of the earth or nearly so. The northern edge or rim of the basin is discovered near the Coquet or Northumbrian stream. The southern edge or rim of the basin is found in the valley of the river Tees, which divides the counties of Durham and York. The western rim is about twenty miles west of Newcastle. The eastern edge of the basin may be covered with a sheet of blue paper, to indicate that this portion rises useless and nearly unworked at the bottom of the sea, although occasionally the hardy miners have pushed their galleries even below the bed of the ocean, to obtain what is termed the ocean coal. Many years ago, a coal pit was worked at Borrowstownness under the sea. The seams of coal were found to continue under the bed of the sea in this place, and the colliers had the courage to work the seam near halfway over, there being a mote half a mile from the shore, where there was an entry that went down into the coal pit, under the sea. This was made into a kind of round key or mote, as they call it, built so as to keep out the sea, which flowed there twelve feet deep. Here the coals were laid, and a ship of that draught of water could lay her side to the mote, and take in the coal. This famous colliery belonged to the Earl of Kincardine's family. The freshwater which sprung from the bottom and sides of the coal pit was always drawn out upon the shore by an engine moved by water that drew it forty fathoms. This coal pit continued, says the narrator of the above account, to be wrought many years, to the great profit of the owners and the wonder of all that saw it. But at last an unexpected high tide drowned the whole at once; the labourers had not time to escape, but perished in it. At the Howgill pits, west of Whitehaven, the mine galleries have been driven more than one thousand yards under the sea, and about six hundred feet below its bottom. These pits have also been visited by fearful floods from undermining the sea too closely and deeply.

It is often a matter of surprise with young persons how the learned geologist or experienced coal engineer can, as it were, look into the earth, and say whether it contains coal or not; because, if coal were deposited in even strata all over Great Britain, a deep hole sunk in any garden would be sufficient to discover it. What kind of spectacles, then, do they put on for this purpose? Why, none are required; the only power demanded is the power of observation; and just as we all know and appreciate a person by the company he keeps, so the geologist or coal

miner knows where to look for coal by observing the appearance of the neighbouring rocks or strata.

The next diagram, showing the basin-like appearance of the coal measures, demonstrates the chief rocks which are the companions and neighbours of coal, and it represents a section of the coal fields south of Malmesbury, in the county of Wilts.

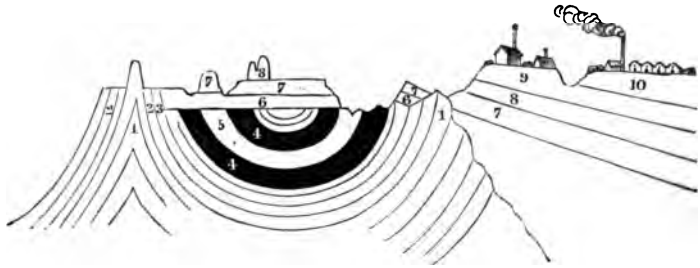


Fig. 19. Section of the Coal Basin S. of Malmesbury.

1, 1. Old Red Sandstone.
2. Mountain Limestone.
3. Millstone Grit.
4, 4. Coal Seams.
5. Pennant, or Coarse Sandstone.
6. New Red Sandstone, or Red Marl.
7, 7. Lias.
8, 8. Inferior Oolite.
9. Great Oolite.
10. Cornbrash and Forest Marble.

The apparent inversion occasionally of the coal strata, by which the basin-shaped deposits appear to be turned upside down, is easily explained by supposing that two basin-shaped formations might occur side by side; and, of course, if the edges of two basins are placed together like c c, Fig. 20, and a section taken through, they would represent a convex coal field, such as that exhibited in Staffordshire, at the Castle Hill, close to the town of Dudley. Through this hill canals have been cut for working the immense beds of carboniferous limestone. This seeming inversion must be regarded as resulting from the approximation of two coal basins, separated by the basset edges of their mountain-limestone repository.

The limestone forms the base of the series of the carboniferous group in the south-west and centre of England, but is more divided in the north; and here, perhaps, the classification of rocks may not be altogether undesirable, as it will demonstrate further the position taken by coal in the assemblage of rocks forming the crust of the earth. In the first place, the whole number of strata may be divided into two great classes—viz.:—

1. Strata produced by the agency of water, or the aqueous formation.
2. Rocks resulting from the action of fire, or the igneous formation;

which may be arranged as follows :—

1. Sedimentary or Fossiliferous Rocks.
2. Metamorphic or Unfossiliferous „
3. Volcanic, as Basalt.
4. Plutonic, as Granite.

Nos. 4, 3, 2, are called igneous and metamorphic rocks, and contain no

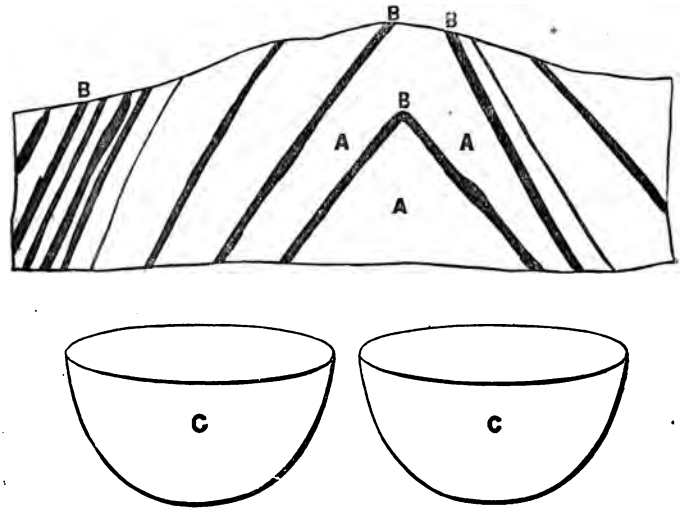


Fig. 20. Convex Coal-field, Staffordshire. A, A A are Limestone Strata; B, B, B, B, are Coal Seams.

traces of coal or fossil remains, whilst No. 1 is fossiliferous, and is again divided into :—

1. The Palæozoic series (most ancient forms of life), or Primary.
2. The Mesozoic series (middle life period), or Secondary.
3. The Cainozoic series (more recent forms of life), or Tertiary.

The Palæozoic or Primary series of the Sedimentary or Fossiliferous rocks include :—

1. The Cambrian Group.
2. The Silurian „
3. The Devonian „
4. *The Carboniferous* „
5. The Permian „

The Carboniferous Group includes :—	Average thickness in feet.
1. The Coal Measures	3000 to 12,000
2. Millstone Grit	600
3. Mountain Limestone	500 to 1400
4. Limestone Shales	1000

Having traced down, as it were, the pedigree and stony relations of coal, our thoughts may be directed, in the next place, to the mode of probing, or "boring," the earth for the purpose of obtaining the last convincing evidence of the existence of coal, before incurring the subsequent expenses of erecting buildings, steam-engines, and machinery for the purpose of working the coal.

It is sometimes a source of regret to unthinking persons that all our coal does not outcrop, or *basset*, and come to the surface, but a moment's reflection will show that, if this had been the case, we might never have enjoyed the abundance we now possess of this invaluable fuel; because it might all have been swept away by those remarkable changes brought about by the action of water, which have washed away or *denuded* the crust of the earth, so as to produce in some places variations in the strata many miles in depth, and moulded generally that delightful appearance to the eye of lofty hills and beautiful valleys. To understand what *denudation* has done, it is necessary to study Mr. Sopwith's instructive models, and especially Model I.

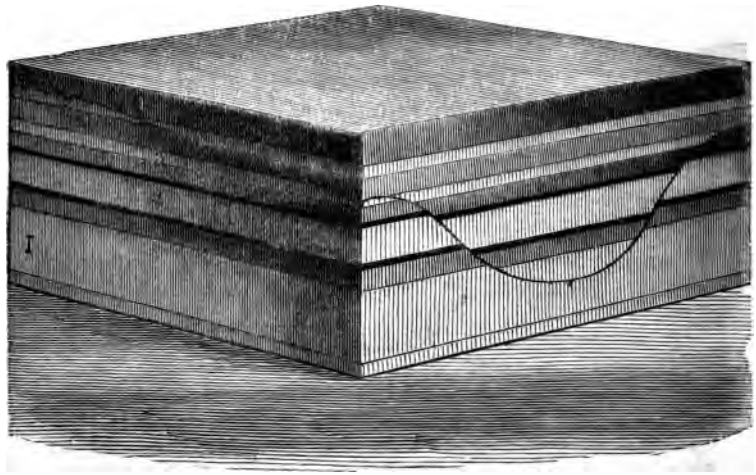


Fig. 21. Sopwith Model No. I. (Tennant.)

This model represents a square mass of part of the carboniferous or mountain-limestone strata, and affords a general idea of the *horizontal*

deposition of strata. The upper stratum marked 1 represents part of an argillaceous stratum, or bed of indurated clay, about thirty feet thick; 2 is a siliceous sandstone rock, about ten feet in thickness, called in the mining districts of Alston Moor, in Cumberland, Pattinson's *sill* (bed or stratum); 3 is a calcareous rock called Little Limestone; 4 are siliceous and argillaceous rocks, accompanied by thin seams of coal, mostly of an inferior quality.

By removing the upper part of the model No. I., the effect of *denu-*

Fig. 22. Hand removing Top of Model No. I.

dation is at once apparent; the various strata are exposed to view. "This," as Mr. Sopwith says, "is one of the first lessons in geology, and when learnt, the student will find in every mountainous region abundant examples of valleys having similar strata, which were once connected, but have been severed by denudation; and hence such valleys are termed *valleys of denudation.* As familiar examples, the valleys of the rivers

Tyne, Wear, and Tees, in Cumberland, Durham, and Northumberland, may be mentioned. In them, the *cropping out*, or basset, of the strata is very obvious, and affords peculiar facilities for geological research. . . . To produce such a valley as that represented in the model, it is obvious that a quantity of rock equal to *the whole of the upper portion of the model* must have been washed away; and it thus affords a useful exemplification of the vast amount of denudation which has taken place, not by gradual operations as ordinary streams deepen their channels, but by long-continued and powerful currents, of the extent of which we can judge only by their vast results."

It remains only to be observed, that the portion of the strata represented by the upper part of the model has, by the process of *denudation*, been carried away. This upper portion of the model, on being removed, may serve, when laid with the surface marked No. 1 upon a table, to

Fig. 23. Sopwith Model. Top of No. I.

exhibit the appearance of strata cropping out or bassetting on a hill, and presenting exactly the converse of the features exhibited by the lower portion of the model. The V form of the strata which points up the valley points *down* the hill, and the inclined surfaces of the hill

present, in a very satisfactory manner, the great variation of the forms of the edges of strata which, in the vertical sections at the sides, are exactly parallel. If all the strata had remained horizontal, and exactly in the order that they were deposited, like a number of books piled one

Fig. 24. The books represent a thickness of about 5 miles, and the hand holding the stick indicates the great depth of the Coal Strata.

above the other, it is evident that the task of procuring the coal would have been one of the most laborious and expensive kind; and it is

doubtful whether the coal could ever have been won from such profound depths.

If it be assumed that the whole series of English stratified rocks, from the highest formation down to the Silurian rocks inclusive, be about five miles, the carboniferous series will be represented by about one-seventh, thus leaving four-sevenths for the thickness of the strata below, and two-sevenths for the thickness of the upper or superincumbent strata; and in order to show how wonderfully Providence has ordered the arrangement of the strata, a number of books may be placed one above the other, so as to represent about five miles of strata.

Here it will be seen at a glance that, had the beds remained in their

Fig. 25. Same as Fig. 24, only tilted on one side.

original horizontal position, the coal strata could not have been reached, as the deepest coal mines are not more than about two thousand feet deep; and, although the thicknesses of the various formations vary in different parts of the kingdom, still the average thickness would have formed an impassable barrier and prohibition of coal. But by the upheaving forces which have, ages ago, disturbed the crust of the earth, the lower strata have been brought to the surface, and it is easy, by placing the hand under the lowest volume, to tilt the pile of books over; so that, instead of being arranged in the ordinary horizontal position, they are now inclined at an angle, and the books representing coal and

other older strata are brought to the surface, and can be touched by the stick.

The task of "boring" must, therefore, always precede the "mining," and where this slow but sure plan has not been adopted, the most dis-

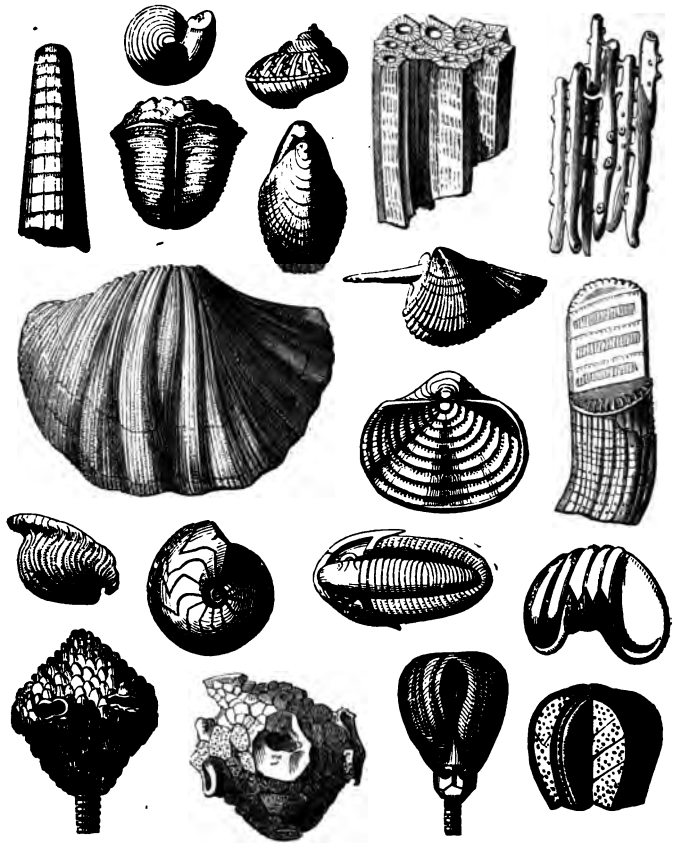


Fig. 26. Fossils of the Mountain Limestone and Carboniferous Shale.

astrous loss of property has occurred. The tools for boring are made of the very best iron and steel—the bore-rods of tough iron, and the

chisels of well-tempered steel; and the former are united together by male and female screws. The chisels work into and bore through the strata, and there is a tool called a "wimble," very much like an auger, whose cavity is from six to ten inches in length, with an opening on one side, and a partial overlap in order to receive, hold, and bring to the surface the bits of broken strata; else the hole would be gradually choked, and the chisel could not be worked, unless cleared from the *débris* as the boring proceeds.

In the Newcastle coal district there are professional master-borers, who undertake to search for coal, and furnish an accurate register of the strata perforated. The average price of boring, in England or Scotland, where no uncommon difficulties occur, is six shillings for each of the first five fathoms, twice six shillings for each of the second five fathoms, thrice six shillings for each of the third five fathoms, and so on.

Whilst searching for coal in any country, its accompanying rocks ought to be looked for, especially the carboniferous or mountain limestone, known by its fossil remains; also, the outcrop of the millstone grit and the newer red sandstone, amongst which some rifts of coal may be discovered, and also fossils presenting the aspect of those in the cut No. 26.

The mining engineer having surveyed the country, and proved the existence and general distribution of the coal strata, and also ascertained that the dip, or incline, of the strata, like the slanting books in Fig. 25, page 43, is towards the south, commences boring the field at the extreme northern part of the dip. He might certainly begin his operations at the south extremity; but then it would be like reading a book backwards, as will be understood by reference to the next cut.

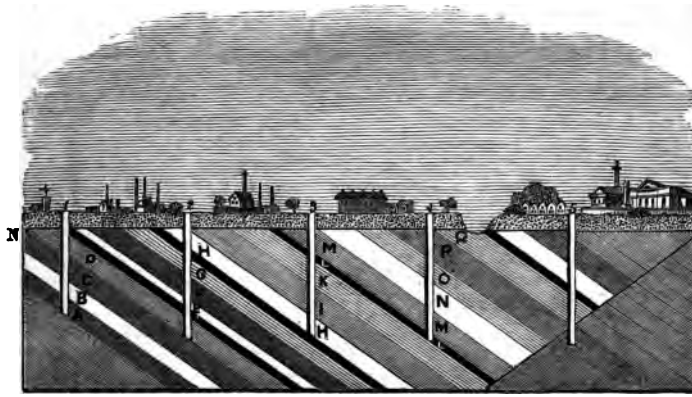


Fig. 27. Mode of "Boring" for Coal.

The first *bore* is made at No. 1, to the depth of sixty yards, and as it is proceeding, the peculiarities of the strata, their quality, and thickness are carefully observed and noted in a journal, whilst specimens of the rocks passed through are preserved. An ignorant person might suppose the labour fruitless because the first probing of the "field" has not touched coal; but there is this satisfaction obtained by commencing at the extreme northern end—viz., that if coal has not been found, it has, at all events, not been lost, and the owner of the coal field consequently discovers, by the boring at No. 2, the exact place where his coal begins. Now, suppose that the dip of the strata be one yard in ten, the question is, at what distance from bore No. 1, in a south direction, will a second bore of sixty yards strike the first stratum D of the preceding? The rule is, to multiply the depth of the bore by the dip—that is, 60 by 10—and the product, 600, gives the distance required; for, by the rule of three, if 1 yard of depression corresponds to 10 in horizontal length, 60 yards of depression will correspond to 600 in length. Hence the bores marked 1, 2, 3, 4, 5, are successively distributed as in the figure, the spot where the first is let down being regarded as the point of level to which the summits of all the succeeding bores are referred. Another bore is therefore made at No. 2, where they strike at E the stratum of coal they could not touch at No. 1—viz., that which is just above D, whilst a second seam of coal is also found at H. A third bore, at the same distance of 600 yards, is again made at No. 3, where they touch at H the same seam already discovered at No. 2, and also make the acquaintance of one other seam, L. At No. 4 they again strike the L coal seam; and now, thinking to proceed triumphantly, at No. 5 to touch other seams, they find, perhaps, that a slip or dislocation of the strata has taken place, which completely bewilders the master-borer, although he may be an engineer of considerable experience. A consultation is then held with other practical men well acquainted with the district, and it is finally determined whether any further cost shall be incurred by deeper borings. It should be remembered that the collier does not speak of digging out the coal as they would of potatoes or other root crops, but proudly says, "I win the coal;" and we may notice in the next place the number of troubles and difficulties the engineer has to encounter in trying to procure the coal; for the same upheaving of the strata which has done so much good in giving him access to it, has also rendered that access frequently hard and difficult, because of the breakage of the continuity of the coal seams by

1. Dykes.
2. Slips, or Faults.
3. Hitches.
4. Troubles
   - Nips, or Wants.
   - Saddle-backs.
   - Baulks, &c.
   - Pot bottoms.
   - Shaken Coal.

A dyke is a wall of rock generally of a nature and age differing from the strata in which the coal is deposited, and dividing or cutting through the beds of coal. In some places the dykes have acted as walls to defend the coal; in others, as levers on a grand scale to upheave it; in others, as partitions to divide it. They appear to be of an igneous origin, and to have been produced by volcanic action coming from below and filling the cracks and fissures in the strata of rocks and coal. The fissure, according to its contents, is called a "dyke," as a "trap-dyke" or a "whin-dyke;" the former being filled with the igneous rock called trap, the latter with another volcanic rock termed whin or basalt.

The effects of slips and dykes in the coal strata are shown in the next cuts, and appear more prominently when viewed in a vertical section than in a ground-plan, where they seem to be merely veins and lines of demarcation, just like the appearance presented when we look down upon the surface of a cracked looking-glass.

Fig. 28 is a vertical section of a coal field from dip to rise, showing

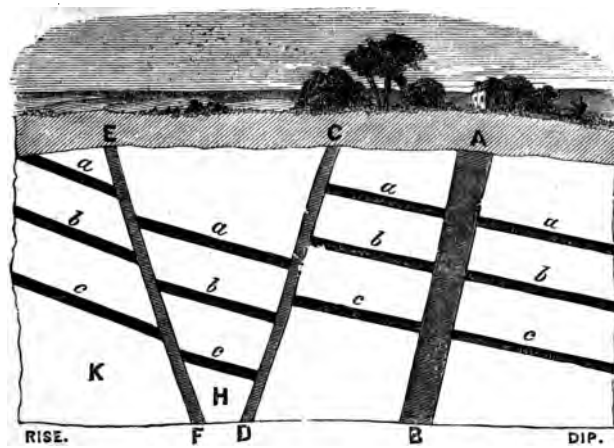


Fig. 28. Dyke Troubles.

three strata of coal, *a*, *b*, *c*. A B represents a *dyke* at right angles to the plane of the coal beds. This rectangular wall merely separates the coal measures, affecting their line of rise; but further to the rise the oblique dyke C D interrupts the coals *a*, *b*, *c*, and not only disjoins them, but throws them and their accompanying strata greatly lower down; yet still, with this depression, the strata retain their parallelism and general slope. Nearer to the outcrop another *dyke*, E F, interrupts the coals *a*, *b*, *c*, not merely breaking the continuity of the planes, but also throwing them moderately up so as to produce a steeper inclination,

as shown in the figure. It sometimes happens that the coals in the compartment H, between the *dykes* C D and E F, may lie nearly horizontal, and the effect of the dyke E F is then to throw out the coals altogether, leaving no vestige of them in the compartment K. These dykes, or walls, are frequently of great value in coal pits, by separating one division of a coal field from another; thus, in the year 1825, a shaft was dug at Gosforth, near Newcastle, on the *wet* side of what is locally termed the great ninety-fathom dyke, which there intersects the coal field. The workings were immediately inundated with water, and it

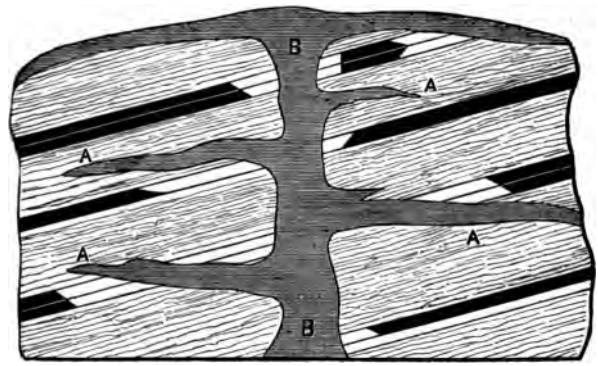


Fig. 29. A Dyke Trouble, and partial Change of the Coal into Cinders.

was found necessary to abandon them. Another shaft, however, was sunk on the other side of the dyke, only a few yards from the former, and in this they descended nearly 200 fathoms, or 1200 feet, without any impediment from the water. When a coal-pit takes fire, which is by no means unusual, the wall, or dyke (like the party-wall of a house), is of the utmost value in arresting and confining the fire to a particular portion of the coal field so invaded. Sometimes the dyke (as in Fig. 29) completely displaces the coal, or reduces it to the appearance of half-burnt cinder. The strata of coal are represented by the dark black lines, and the main channel of the dyke at B B, showing at its arms A A A A, near which the black lines are broken and discontinued, the natural formation of coke or cinder in the earth by the heat probably given out by the once melted and heated mass of whin, or basalt. This curious fact appears conclusively to demonstrate that the dyke rocks must have been in a liquid state, like lava, or they could not have affected the coal in the manner described. It is right to mention that the advocates of the Neptunian theory insist upon the formation of these so-called igneous rocks by deposition from solution in water, and they meet the question of the conversion of coal naturally into cinder by stating that it has arisen from a spontaneous heat generated by natural changes in the coal itself.

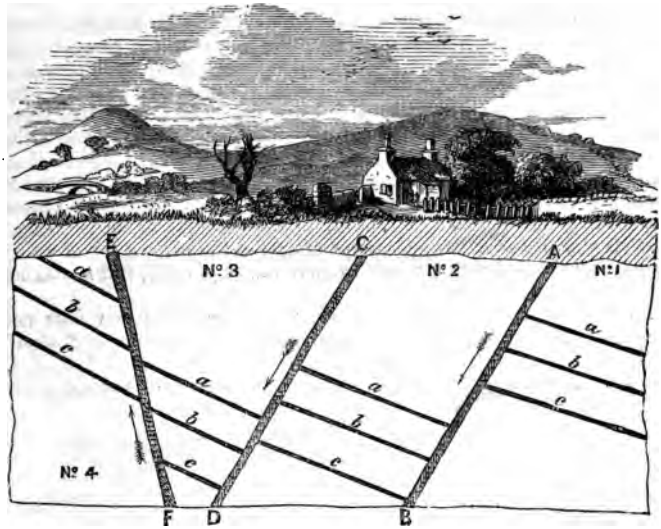


Fig. 30. Slips, or Faults. The arrows show the direction of the down-throw and up-throw.

The effect of a slip, or fault, in breaking the continuity of the coal seams is shown in the above diagram, where we may suppose the coal is

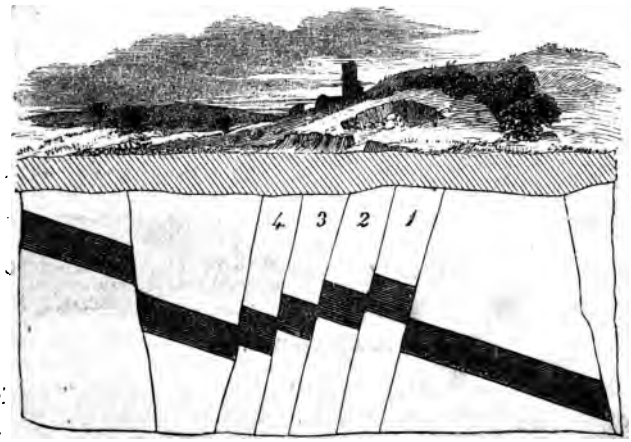


Fig. 31. A Hitch.

being worked from the seams *a*, *b*, *c*, and is found to be disturbed by an intersecting slip, A B, which throws all the coals of the compartment No. 1 much lower, as shown in No. 2; and this is what is termed a "*Down-throw*," or "*Jump-down*." Another slip, C D, has produced similar results in a lesser proportion, when *a*, *b*, *c* are thrown still lower in No. 3. E F represents a slip in the opposite direction, by which the coals (*a*, *b*, *c*) are thrown up, and this is called an "*Up-throw*," or "*Jump-up*," as shown in the compartment No. 4. The appearance produced by faults is often very deceptive, and has sometimes caused considerable loss and disappointment, in consequence of inexperienced persons observing various indications of coal at the surface (all of which arises from the dislocation of one or more seams of coal), and mistaking them for separate seams of coal.

Hitches are small and partial slips, where the dislocation does not exceed the thickness of the coal seam. The miner's term of "*steps*" is well applied to this freak of nature, and is displayed at 1, 2, 3, 4, Fig. 31. As before noticed, when the miner digs into the earth for

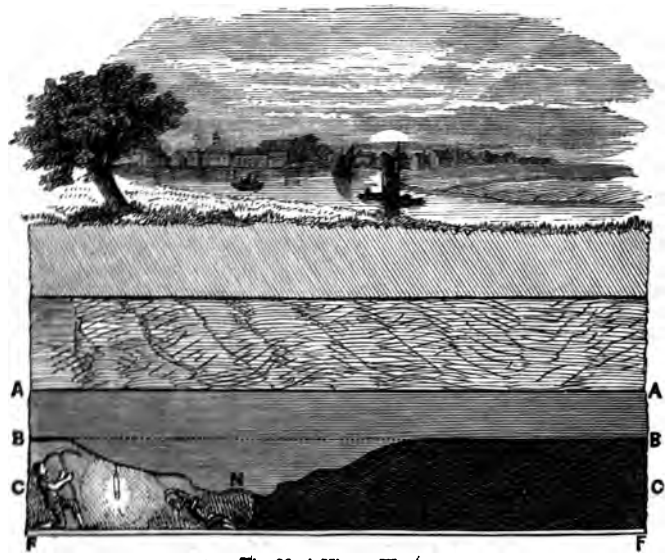


Fig. 32. A Nip, or Want.

coal, he almost opens for himself a Pandora's box of "*troubles*," which are termed nips or wants, saddle-backs, pot bottoms, shaken coal, &c.

A nip occurs where the rocky stratum just above the layer of coal

invades the thickness of the precious fuel below, and, elbowing it away, takes the place of the coal; here, instead of digging out coal only, a considerable portion of the rock has to be removed; hence, where coal is not, there must be a "want," or nip, and this condition of the strata is shown at Fig. 32. A B represents the thickness of the rocky stratum above the coal, C C. The floor is shown at F F, and the stratum A B has descended into and nipped out the coal at N. A pot bottom is a modification of the same trouble. Saddle-backs and gaws appear to be the reverse of nips, as the floor is either irregular or rises into and interferes with the continuity of the coal stratum, again causing profitless labour in order to level the rock to admit of the rails being laid down for the rolleys or trucks to roll on. Shaken coal appears to be coal which has been completely crushed or ground by some extraordinary pressure and movement of the strata. It very much resembles the rubbish of an old waste, being a mere shapeless heap of coal dust, which is often so soft that it may be dug out with a spade.

The fact of coal being charred by the presence of a whin dyke would seem to prove that the rock forming it had once been in the liquid state; but the advocates of Neptunian action find no difficulty in urging that the coal may have become heated like a damp haystack, and thus spontaneously brought about its own change by internal chemical action, without the assistance of Pluto and his molten and red-hot rocks. One of the most interesting examples of this curious change in coal is that of the whin dyke in Cooper Colliery, near Blythe, Northumberland, and related in the "Philosophical Magazine," 1827. "The total length to which this dyke has been traced is 1577 yards. It increases in breadth from south to north, being 4¾ yards wide near the most southern point where it has been cut through, and 21½ yards wide at the most northern spot. It is formed of two walls of greenstone, each from two to four feet in thickness; and these walls contain between them a brecchia composed of fragments of shale and whin cemented by calcareous and argillaceous matter. Carburetted hydrogen and pure water issue from a narrow fissure in the broadest part of the dyke. The coal of the beds through which the dyke passes is *charred* and deteriorated in quality to the distance of about forty yards on each side."

COAL-MINE MACHINERY.

When coal mining is conducted even in the rudest manner, there must, of course, be a deep well or pit dug into the earth; and supposing the miner should meet with the usual occupant of wells—viz. water—it is evident that provision must be made either to bale it out by tubs, or some kind of pumping apparatus must be employed for that purpose. Moreover, the collier must not only be kept dry, but he must have air, and plenty of it, too, or his health is rapidly undermined, and he becomes prematurely old and worn out. In other parts of this book the details of mining will be gradually explained; and, instead of tiring the youthful reader with the whole at once, they will be spread through

the various chapters on the metals. The most simple arrangement for draining and giving air to a mine, and one which is extensively employed in America, is that of the day level, where the miner commences at the level of the water at M, Fig. 33, and burrowing into the ground, intersects the coal seams F, E, D. A perpendicular shaft, P, meets this level, and cuts through the coal at C and B. So far the mine is drained by

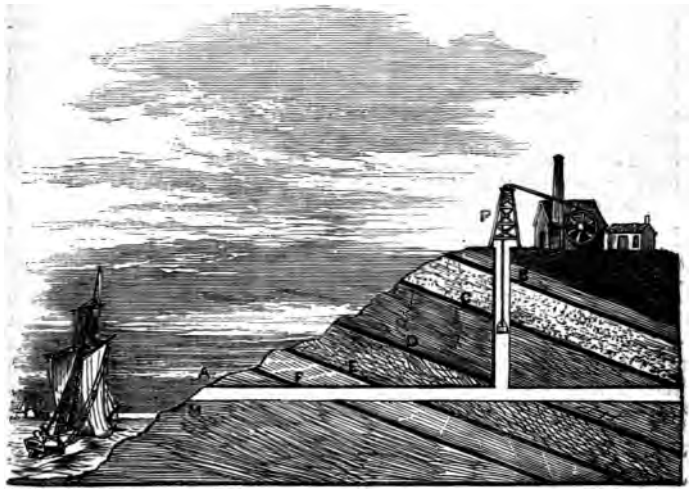


Fig. 33. "A Day Level."

the level A, and ventilated by the shaft P; but if they require to go lower than the level A, a steam engine and pumping apparatus must be placed at the top of the shaft, P, for the purpose of lifting the water to the level A, along which it would flow till it fell into the sea at M.

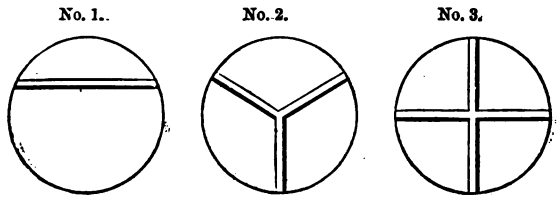


Fig. 34. Various Methods of dividing a Coal Pit Shaft for Ventilation and drawing Coals, &c.

Such a gallery, or nearly horizontal excavation, is called a day level; it corresponds with the "adit level" of a mineral mine, and saves expense in fuel, machinery, and pumps.

The usual method of winning coal is, however, to sink a circular pit or shaft; and this is subsequently divided by wood work into two compartments, one being devoted to the pumps, and the other for ventilation and drawing the coals; and this is called a double pit, No. 1. Sometimes the shaft is divided into three parts, one of which is occupied with the pumping gear, and the other two for ventilation and raising the coals; and this is termed a triple shaft, No. 2. A quadrant shaft is divided into four compartments, one being occupied with the pumps, and three for ventilation and coal drawing, No. 3.

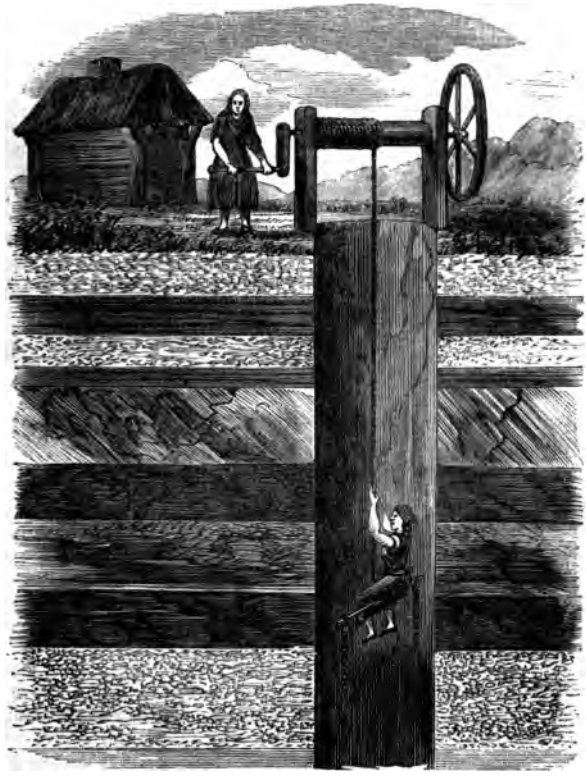


Fig. 35. A Coal Pit worked by Women, as described by Mr. Scrivea in "Blue Book."

The rudest modes of working and winning the coal were disclosed in the report of the Government Commissioners in 1841; one of whom, Mr. Surgeon Scriven, gives some graphic pictures indicating the squalid misery which prevailed in some of the coal districts. In the Yorkshire coal field of the West Riding he describes the use of the "turn-wheel." Mr. Scriven very properly says, "It is the least expensive, and certainly the most dangerous, as you are upon all occasions dependent upon the man, or it may be the woman, who works it. It is, in fact, nothing more or less than a common well-winch, with a fly wheel; without trap-door or stage, conducting rods, or anything else. In getting on or off the clatch iron or corve, in coming up or going down, you are at the mercy of the winder." At the very pit, shown at Fig. 35, a certain Daniel Pellatt was actually drawn *over* the roller, and killed by falling from the top to the bottom of the shaft; and it is painful to record that this man's uncle and grandfather were at work at the winch at the time, and their attention was diverted by a passing funeral just at the moment they had drawn their unfortunate relative to the pit's mouth. In the same picture (Fig. 35) is shown the dangerous and barbarous method of drawing up a female on the clatch iron by another woman. "As soon as she arrived at the top, the handle was made fast by a bolt drawn from the upright post; the woman then grasped her hand, and by main force brought her to *terra firma*." The corve, or basket, on these occasions, is detached from the hooks, to render the load lighter.

The "horse gins" are turned by horses, and work much upon the same principle as steam engines, with this difference, that the drums are elevated eight or ten feet above the ground, and revolve horizontally. (Fig. 36.)

Of the two methods—viz., by the turnwheel or roller and the horse gin—Mr. Scriven considers the latter (provided the appointments are in good condition) the least dangerous, as the strength of the horse, even if disposed to be *restive* (which would be a most *uncommon* circumstance), is seldom sufficient either to draw the basket over the pulley or break the rope, the horse usually being a wretched, wind-galled, spavined, blind, and broken-down animal, and driven by a child. The motion, in coming up or going down the shaft, is of course regulated by the qualities of the animal, or depends upon the attention of the child that drives it: it is sometimes quick; at others slow, jerking, and disagreeable. If the shaft happen to be deep, you will probably have the benefit, says Mr. Scriven, of some half-dozen turns of the rope, by which a swinging motion is given to the basket or corve; the chances, then, are that you get a blow from the other ascending, or strike the sides of the shaft, with the danger of being instantly thrown out.

Some few of the "gins" have the excellent contrivance of conducting rods. These are four iron bars, extending from the frame above the shaft to the halt-stake at the bottom. They are made to pass through a ring at each end of the clatch iron; by which means the corve, when suspended, is kept steady and in its proper place, so that it cannot by any possibility strike in its descent the ascending corve, or separate the

loose rocks that form the sides of the *unlined* shafts; they are also the medium for the conveyance of signals from below. By striking them with a piece of iron one or more times, the sound is audibly heard at the top, and in calm weather at a distance of half a mile.

But, of course, now, at all the best and first-class coal pits, steam engines and machinery of the most perfect description are employed; and whenever the traveller journeys in the coal districts, he is pretty well

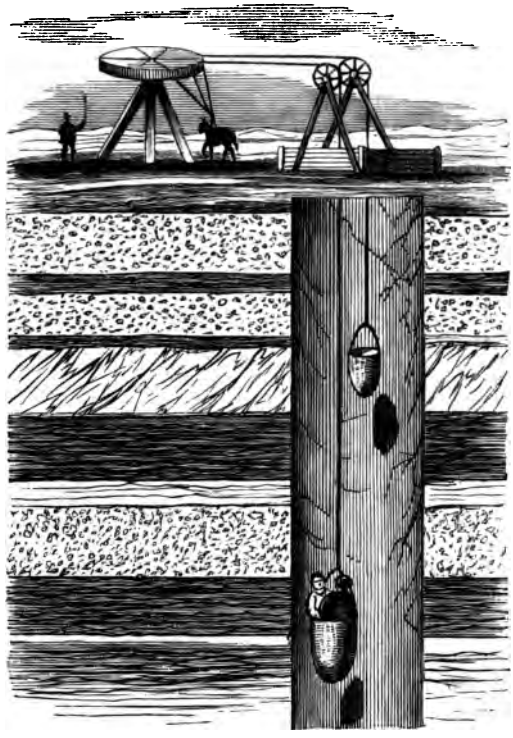


Fig. 36. The Horse Gin used for drawing Coals, &c.

sure to see the great wooden shaft erected over the mouth of the coal-pit, with its accompanying engine-house and chimney, the puffing steam, and beam outside, working up and down, whilst the giant fly-wheel regulates all by its steady motion.

The picture Fig. 38 offers a good example of the better class of

machinery used at coal-pits for raising the men and coals, where the corves or baskets are abolished, or nearly so, and tubs used instead, which hold from six to twelve hundredweight each. These are placed on a frame which works in a slide; and by this means the coals are brought up much quicker to the pit's mouth.

At many of the Welsh collieries, in consequence of the coal being "won" in large irregular blocks, it is drawn up in what are termed

Fig. 37. A Welsh "Pyche."

'pyches." These consist of a bottom floor, or stage, on wheels, and as he coal is packed on it, open frames are placed one above the other, so as to retain the coal, and prevent it falling out of its place.

With the discussion of the machinery for raising the coal we come at once to the mouth of the pit, down which the reader is invited to travel in imagination, for the purpose of seeing all the wonders to be noticed in these underground hives of industry.

"Descent of a Coal Pit."

(AUTHOR'S NARRATIVE.)

Having been invited to deliver a course of lectures at the Philosophical Institute at Newcastle-on-Tyne, my first inquiry would naturally be directed to coal mines, and asking for introductions to some of the coal owners, I was much amused on being told "that I had better finish my course of lectures before going down a coal shaft." The descent, however, of a coal shaft furnished with good machinery and

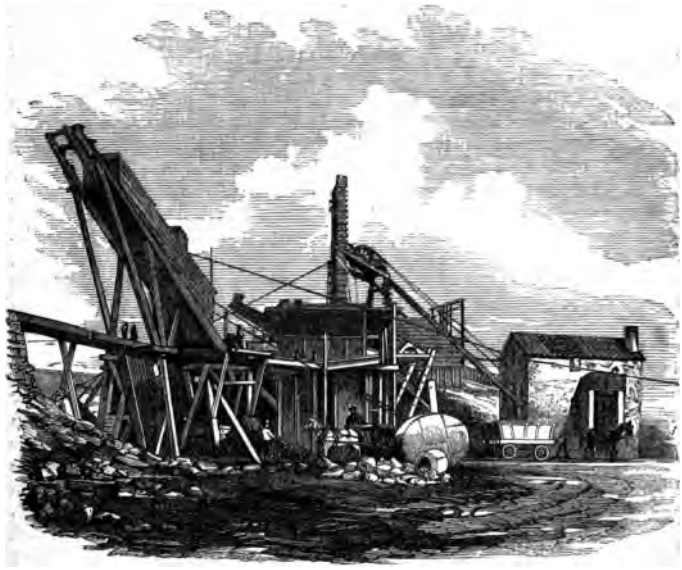


Fig. 33. "The Keepier Mine," near Durham.

draw-ropes is no more dangerous than a railway trip; and after receiving a proper pass, through the kindness of my late lamented friend, Mr. Ralph Dixon, I went early one morning to the station, where I was told to go down the line until I came to another one almost at right angles, where I should see the full trucks of coal descending and the empty ones going up. Attending to my instructions, I was soon at the mouth of the "Keepier Mine;" and as punctuality was the order of the day, did not wait long before the coal viewer, or overlooker, intro-

duced himself to me by asking in a stentorian voice, "Whether I was the gentleman who was going down the shaft that morning?" A brief rejoinder in the affirmative provoked an equally summary reply, given in gruff and plain-spoken language, and I was ordered to "Step in here"—viz., into a little house, or office, where the coal viewer, again addressing me, said, "Now, sir, you must take off your clothes." This in the abstract was rather disagreeable, considering it was winter-time, and that the ground was covered with snow; but of course he had provided other garments, and I was soon equipped in the regular miner's attire—viz., a sort of short rough pilot-coat, flannel continuations, and a very greasy-looking cap. My guide being a most intelligent person, seemed to divine that I wanted to see everything, so he politely asked if "I should not like to see the drawing machinery first?" And away we went to the steam-engine house, where we found, as usual, the beam of the great engine poking its nose out of a sort of upper window, and making continual bows in connexion with a rod and crank working the drums on which the ropes are alternately wound and unwound. We found the engineer inside, seated and looking at his tell-tale, which consists of two pieces of wood attached to a string, and working up and down in connexion with the machinery in front of a piece of black-board. The bits of wood are supposed to represent the corves, or baskets, and by watching their position, the engineer can tell with the greatest accuracy the exact position of the corves in the coal shaft (Fig. 39); moreover, a bell rings as the corve approaches the pit's mouth, and again rings when it reaches the top of the shaft. If the greatest care was not taken in this respect, the corves, with their live or dead freight, would be drawn over the pulley, and such accidents as the following might continually occur:—

"An accident occurred at one of the pits belonging to Earl Granville, at Star Green, Hanley Potteries, by which ten men were killed and other ten severely injured. At half-past two, a 'cage,' containing fourteen men, was being drawn up the shaft of the 'big pit,' while another cage with six or seven men in it was going down at the same time. As the ascending cage drew near the surface, the signal-bell in the engine-room sounded as usual, in order that the engine might be at once stopped. The engineer was, however, too late in attending to his signal, and the consequence was that one cage was drawn up beyond its proper point, while the other went to the bottom of the shaft with a heavy shock. The ascending cage was drawn up till it reached the wheel over which the rope attached to it worked, and was being taken round, when the whole fourteen men, with one exception, were precipitated beneath. Six fell down the shaft, and were dashed to pieces; three fell on the pavement at the pit's mouth, and one on the iron pavement, and was killed on the spot; four who were thrown on the ground received fearful injuries. The occupants of the descending cage were all more or less injured by their fall, but none of them were killed."

In this case the poor men were drawn over the pulley, but in the next case described, the accident occurred from the drum (round which

the rope is coiled) being improperly connected with the machinery. It happened near Wolverhampton, and resulted in the instant death of seven persons. "At a little before six o'clock, the colliers at the Blue Fly Pit, at the Wednesfield Heath Colliery of Mr. H. B. Whitehouse, assembled around the pit's mouth to descend to their work, down a shaft nearly one hundred yards in depth. During the previous night the engine had been used in drawing water from the pit, and on Saturday

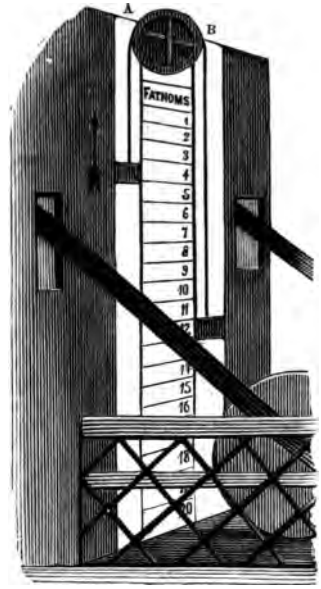


Fig. 39. The Tell-tale, which shows the position of the tubs in the shaft.

morning the night engine-tender had left duty, and the engine-tender for the day had taken the engine in charge. On passing each other, the engine-tender who was going off duty said to his successor, 'It's all right.' Presuming upon the supposed truthfulness of the statement, the day engine-tender went confidently into the engine-house, and the colliers received the customary signal to jump into the skip; four men and three boys obeyed the signal, the engine was set in motion, and the skip raised a few inches from the wagon or platform that on such occasions forms the temporary covering to the mouth of the shaft, and the waggon was drawn away to allow the skip to descend. The engine had been scarcely reversed before it was found that the drum upon which the

wire-rope that held the skip was coiled had been imperfectly connected with the engine. In no way held in check, therefore, it began to revolve with great rapidity, and in an instant the men and boys in the skip were literally dashed to atoms at the bottom of the shaft."

It must be evident, from the consideration of these two accidents, that

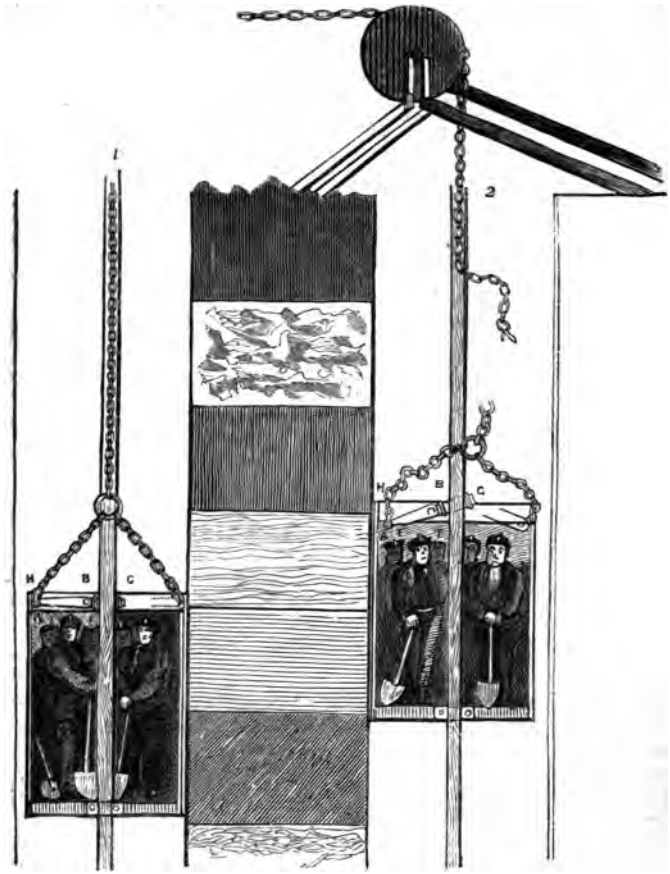


Fig. 40. Aytoun's Patent Safety Cage. 1. Cage descending and chain unbroken. 2. Chain broken, catch disengaged, and the cage stopped by the shoes or slides biting into and fixing themselves on the guide-rod.

safety-cages are of the greatest value, even when the rope is carefully attended to. Neither of the accidents related was owing to any deficiency in the rope or gearing, and yet seventeen lives were sacrificed, not one of which would have been lost had a safety-cage, with its disengaging catch, been in use. One of the most simple contrivances (Fig. 40) for that purpose is the invention of Mr. R. Aytoun, of No. 3, Fettes-row, Edinburgh, and is thus described by the inventor:—

"The only novelty in this cage lies in the upper sides, or shoes, and their appendages. These slides, or shoes, B C, B C, are two in number; but being placed on opposite sides of the cage, only one of them can be seen in the drawing. Each of these slides, B C, has a single bolt, or stud, B, by which it is attached to the cage, and around which it turns; a long arm, A B, to the extremity of which the winding chain is attached; a stop, H, which prevents the arm from being pulled above the horizontal line; and a spring, E F, which lowers it when the winding chain is slack.

"From this description it is easily seen that, in the event of the rope or gearing giving way, the springs, E F, E F, so tilt the shoes, or slides, B C, B C, that they immediately seize hold of the guide rods in the same manner as a boring key in the hands of a miner lays hold of the boring rods, and with the same tenacity of grip; and although the rope should come down on the top of the cage, the only effect would be to cause the shoes to dig deeper into the guide rods, and thus to make the hold more secure. The means of arresting the cage in its descent being thus provided, there need be no hesitation in adopting the 'disengaging catch,' whereby, in a case of over-winding, the rope is let go and the cage remains safely suspended from the guide rods.

"It may be mentioned that the safety apparatus costs little money, and can be fitted to existing cages. Moreover, when brought into action, it does not injure the guide rods, and consequently, after an accident, in which lives and property may have been saved, the winding may be proceeded with almost immediately.

"To ensure the speedy adoption of this invention, the licence fee for a single cage, during the existence of the patent right, has been limited for the present to 1*l*."

Before the act was passed regulating the labour in coal mines, mere boys were often employed to attend to the drawing apparatus, and it will be remembered that the great George Stephenson fulfilled this kind of duty in the early part of his industrial career. It has been said, with great truth, that one boy alone at work, is a boy; two boys are equal to half a boy; and three boys together are equal to no boys, because they follow their natural instinct and do nothing but play; hence the Act of Parliament orders that no lad shall be placed at the very responsible duty of attending to the breaks who is of a less age than fifteen years. With this digression on the subject of pit machinery and the risk of over-drawing, we return again to the personal narrative.

"Having examined the engine and drums, ropes, &c., I could not help saying to my guide, 'Does the rope ever break?' 'Oh yes, sir,

but we are going to give you the new 'un, and now, if you are ready, we'll go to *bank*.'

"'Going to bank' means going to the pit's mouth; and if the visitor has never looked down a pit before, it certainly does seem to be a very dark, yawning, and most dismal orifice or entrance to the riches of the coal mine. The observer, however, has not time to reflect on the dangers of the middle passage, for all is bustle and activity at *bank*, and everything seems rattling, creaking, and noisy, giving ocular proof of the most zealous industry. Really, going down coal pits ought to become very fashionable, considering that H. R. H. the Prince of Wales and suite visited Houghton Pit, the property of the Earl of Durham, which they descended, and were conducted through some of the workings by Mr. Heckels. The Royal party were conveyed from the bottom of the shaft down the 'engine plane' into the workings in coal tubs, and remained in the pit about an hour and a half. The young Prince, who made frequent and pertinent inquiries of his conductors on different matters, was shown the mode of working the coal, &c. He evinced no symptoms of trepidation at the prospect of being let down the yawning abyss, and in this respect his conduct strikingly contrasted with that of the late Emperor Nicholas, of whom it is recorded that, after preparing to descend a coal pit in this neighbourhood, his heart failed him when he reached the mouth of the shaft, and he declined the perilous journey, declaring it was like looking down into the infernal regions.

"But my companion did not suffer me to waste time, so, once more asking whether I would go down, and receiving a cheerful 'Yes,' he put his head over the shaft and emitted the strangest sounds I ever heard. They seemed to be a mixture of every kind of bellow that one could possibly listen to, and after waiting a minute or so, I could not help inquiring why he did not receive an answer. 'Oh! you wait a bit, and you'll see,' was the rejoinder; and presently a corve full of coal came to *bank*, and on it was the desired answer in the shape of a bit of greasy tow; which telegraphic signal meant that a nice new corve was coming up for me, but that they did not intend to waste time by sending it up empty, as some of the colliers would take advantage of the carriage and come to the surface. Again the bell rang, the engine wound up the rope with its living freight slower and more carefully; the warning bell rang as the top of the chain emerged from below, and more chain coming into view, disclosed a cluster of boys clinging like sailors to the bare chain above the corve, in which were two or three grave-looking men. The engine bell rang again just before the rim of the basket touched the edge of the pit's mouth; and the corve being stopped, the men were dexterously handed out, and the boys liberated from their perilous position; and although the gravity produced by hard labour was apparent on all countenances as they came into daylight, it quickly changed into hearty merriment when they discovered me aping their attire and standing at the brink, a real live cockney, and ready to descend. I did not, however, wait long to stand the brunt of their inquiring glances and complimentary speeches; but, obeying the word of command to 'Jump in,' I

was soon located in the corve, or basket, and down I went at a speed which appeared to be very great. I was rushing and tearing through the air, in a downward direction, at a pace that seemed perfectly

Fig. 41. Men and Boys "coming to Bank."

frightful; indeed it was a good emblem of life, and having taken that downward course, it was of no use to alter my mind—I could not jump back again.

"As the corve descended, I could not help looking upwards, when I discovered that the great yawning orifice had dwindled away apparently into one of about the diameter of the hole in an ordinary coal-cellar when the plate is removed; but thinking of a possible visitation from some of the lumps of coal I had seen at the pit's mouth, I quickly reversed the direction of my gaze, and found myself tucking my chin into my waistcoat, to avoid the chance fragments of coal, but instantly

Fig. 42. Descent into a Coal Mine.

reassured, I peered downwards, and then noticed the increasing warmth of the air. Presently a slight reddish glow of light was apparent, but before I could perfectly collect my senses, the basket gently touched the bottom of the shaft, and two or three sturdy fellows rushed at me with a 'Now, sir.' I was soon pulled out, another corve full of coal was tacked on to the rope, and away it went upwards, whilst I was

conducted through darkness visible to some kind of seat, where I was gently thrust down, and told to wait a bit till 'I got my eyes,' for the sudden change from full daylight to the darkness of the coal pit produced that want of confidence which is so apparent when visitors at the Crystal Palace step from broad daylight into the darkened lecture-room when dissolving views are being displayed.

"The shaft that I descended was called the '*down-cast*,' and this represents the beginning of a system of ventilation which ends with another shaft called the '*up-cast*.' That is to say, fresh air is always passing down the former, it circulates through the intricate labyrinth of galleries or excavated tunnels of the coal pit, and, after having performed its office, escapes at the up-cast shaft. It might be asked why the air does not sometimes prove refractory and reverse its path, but that is prevented by a furnace which is kept burning night and day at the bottom of the coal mine. The chimney conveying away the heated air from the furnace terminates in the 'up-cast,' and by the constant ascent of warm air in the latter, the direction of the ventilating currents is established, cold air passing down the 'down-cast,' and hot and fresh air travelling up the 'up-cast.'"

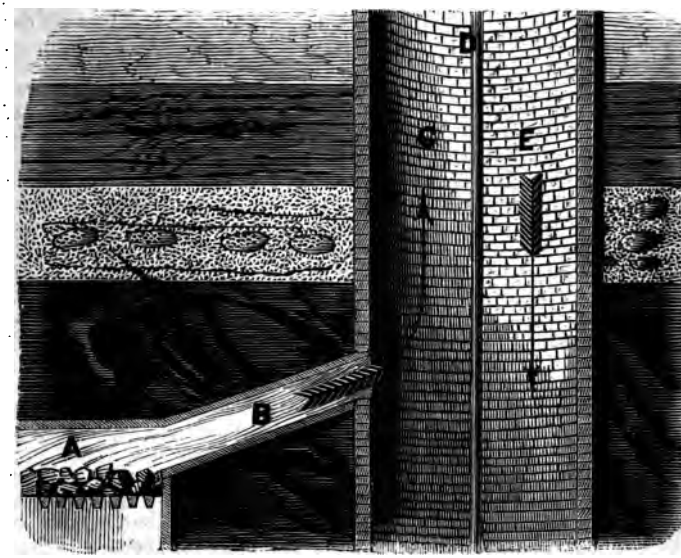


Fig. 43. A. Furnace. B. The furnace drift. C. The upcast shaft. D. The brattice, or timber partition separating the up-cast from E, the down-cast, from which the air travels to the various galleries of the pit, passing to the furnace A B, and so to the up-cast C.

As already explained at page 52, sometimes the mine is provided with one shaft only, which is divided into two, three, or four compartments, and called a bratticed shaft; but this cannot be so perfect a system as that which includes separate shafts for the entrance and exit of the air; moreover, when bratticed shafts are used, the heat of the furnace which establishes the movement of the air must be greatly reduced, for fear of setting fire to the woodwork of the *brattices*.

In the ventilation of mines there are certain rules laid down, the proper application and modification of which, to meet given circumstances and localities, must depend on the judgment and practical experience of the engineer. These rules are:—

1st. That a current of air through the channels of collieries, at a rate of five feet per second, is sufficient for almost all purposes.

2nd. That a current exceeding that velocity will be obtained at the expense of leakage and other evils.

3rd. That, in order to obtain the requisite supply of fresh air, the channels of a mine ought to be enlarged according to the exigency.

In mines evolving fire-damp it has been found necessary, in practice, to have as large a ventilation as 300 cubic feet per minute per man; and if it be assumed that about eighty men and boys are required to work 100 tons per day, a mine working 200 tons per day would require 48,000 cubic feet per minute, and a mine producing 400 tons per day would demand a ventilating power of 96,000 cubic feet per minute. Taking as an example a colliery producing 200 tons per day; if five feet per second be taken as the standard velocity of the air, it follows that the intake and return air-channels should have a sectional area of 160 square feet, or about six feet high by twenty-seven feet wide—dimensions which would be found too expensive, and possibly in many cases impracticable. This assumes that the air would have to pour in one undivided channel through the whole of the mine, and in that case it would, in some large mines, have to travel as much as thirty miles. But in practice it is not usual, even in the best-conducted mines, to give to the air-channel a sectional area of more than fifty square feet, and in many cases, particularly in South Wales, not more than sixteen square feet.

An idea may be formed of the elaborate nature of mine ventilation by the examination of the next cut, which represents a ground-plan of a coal mine supplied with down-cast and up-cast shafts.

This pit contains three furnaces, which communicate with the "up-cast." The air enters by the down-cast, courses round the goaf, or deserted portion of the coal mine, and finally escapes at the up-cast.

When the air is supplied to a mine by one entrance only, and is made to travel by stoppings and doors up and down every part of the works, it necessarily forms a continuous chain and current of air, which may be sometimes thirty or more miles in length, and terminates in the up-cast. This system, which is not a good one, is called "coursing" the air. It follows, therefore, that, if it were attempted to course the air in one continuous channel of sixteen square feet, the current would be

16 feet per second, or 50 feet per second with an air-channel of 50 square feet sectional area—velocities which it would be impracticable

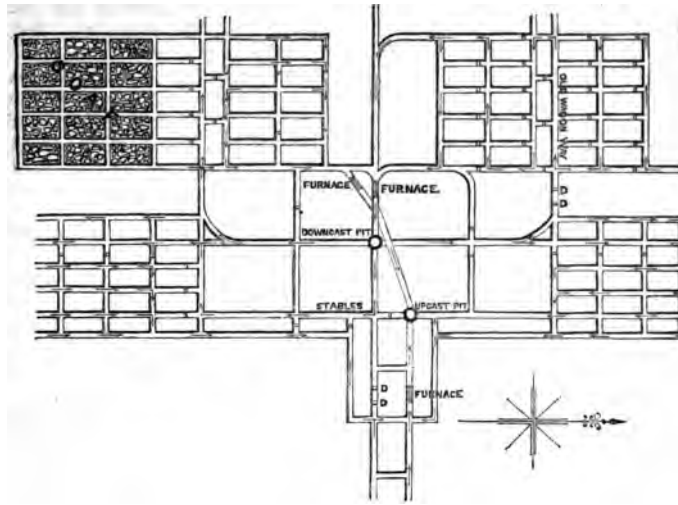


Fig. 44. Part of the Ground-plan of a Coal Mine.

to keep up through the workings, because the rarefication necessary to produce such a current would cause the air channels to leak, and the air to find a shorter course, through the excavated portions of the mine, to the up-cast shaft. The system of *coursing* has therefore given way to that of *splitting* or dividing the currents of air, which are conveyed to separate compartments of the best-arranged mines in the North, and in the same manner as they form distinct workings, so has it at last been found practicable to ventilate each separately. Therefore, if a panel or compartment of work of a mine producing 200 tons per day contains twenty-seven men, the provision to be made in the ventilation for this section of the colliery, at the rate of 300 cubic feet of air per minute per man, would be 8100 cubic feet, or one-sixth of 48,600 cubic feet, per minute; and if this ventilation is kept separate from the remainder of the colliery, the air will necessarily be much purer, and will have to travel a proportionably less distance. Moreover, the velocity through the air-channels will be reduced, in a passage having an area of 50 feet, from 16 feet per second to 2¼ feet per second; or, in a passage of 16 feet area, from 50 feet per second to about 8⅓ feet per second. This latter velocity would still be too high; but by the *splitting* system a multiplication of air tubes may be obtained for the intake and return.

air currents of the mine, producing the same result as would be obtained from one large tube of the aggregate area of the several splittings, with a diminished distance for the air to travel in the same proportion.

The motive powers in most general use for accelerating the air-currents of mines are—1st. The furnace. 2nd. The steam jet. 3rd. The pump, or apparatus such as Struve's mine ventilator.

The use of the furnace has already been described, and in some cases the average temperature of the air in some of the up-cast shafts of the mines in the North was from 140° to 160° Fahr. From the minutes of evidence taken in 1849 before a committee of the House of Lords on the ventilation of mines, the following extract is selected:—

The Haswell Colliery.

Depth of shaft, 936 feet.
Area of down-cast pit, 110 superficial feet.
Area of up-cast pit, 58 superficial feet.
Average temperature in down-cast pit, 62°.
Average temperature in up-cast pit, 165°.
Velocity of air in up-cast pit, 27$\frac{1}{8}$th feet per second.
Quantity of air discharged, 94,000 cubic feet per minute.
Consumption of fuel, 4 tons in twenty-four hours.
There are ten splittings of the current of air; the average area of each is 42 superficial feet, making an aggregate of 420 superficial feet; the distance travelled in each splitting is 3$\frac{1}{2}$ miles.
Estimated power of the up-cast pit, 34$\frac{7}{10}$ths horse-power.

Ventilation of mines by the steam jet originated with Mr. Goldsworthy Gurney, who proposed its use in 1835; and it consists in the arrangement of boilers and steam-pipes at the bottom of the up-cast, which are fitted with twenty or more jets, and as the steam escapes up the shaft, a rush of air takes place from the other parts of the mine towards them, and promotes a constant flow or current of air through the galleries. This mode of ventilating mines, though ingenious, is considered to be expensive to maintain, but is found to be very serviceable in any case where temporary ventilation is required in a coal pit, and there happens to be boiler-power to spare. In the "Boy's Playbook of Science" the steam jet is fully explained and illustrated. The principle upon which Goldsworthy Gurney's steam jet acts is very simple, and depends upon the constant rush of air which takes place towards a jet of escaping steam. The fact is well illustrated by standing on the brickwork at the top of a boiler, and asking the engine man to let off some steam by the safety valve or other aperture; and if a light silk handkerchief is held near the centre of the escaping cone of steam, it will be instantly drawn in, and, like a finger-post, will clearly demonstrate the direction taken by the surrounding air. When steam is allowed to escape from a Marcet's high-pressure boiler, the air rushes towards the inverted cone of steam, and if a light copper ball is placed in the escaping steam, it is held up and supported in spite of its gravitating power towards the earth, as shown in the next cut.

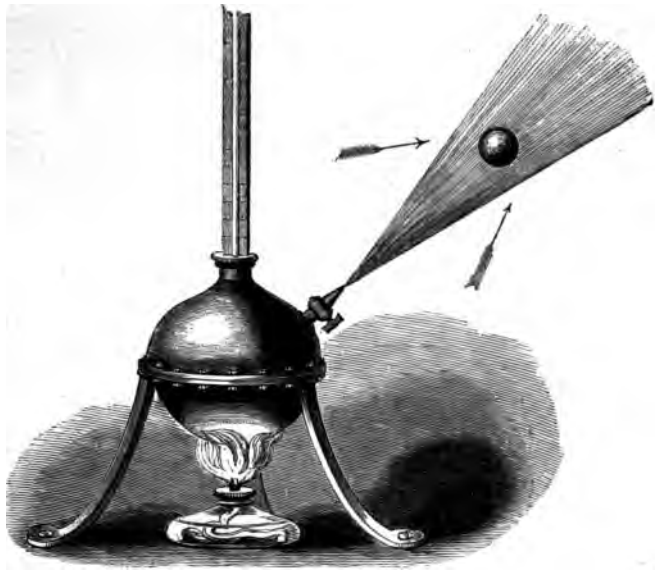


Fig. 45. Escaping Jet of high-pressure Steam, supporting a hollow Copper Ball. The Arrows show the direction of the air, which rushes to the steam.

Mechanical ventilation may be effected by pumps, screws, fans, pneumatic wheels, or modifications of pumps, such as Struve's apparatus (Fig. 46), used at the Eaglehurst Colliery, near Neath, where the up-cast shaft is only nine feet area, and yet the ventilation is worked by a five horse-power engine; and it is calculated that if steam jets were substituted, four boilers of thirty feet each would be required. Struve's apparatus consists of two aërometers or gasometers, E E, made to balance each other, and to move vertically in the spaces J J, by means of the guide rods F F; the spaces J J are filled with water, forming a packing or stop to prevent any air passing from the interior of the aërometers to the chambers above them; the guide rods, F F, are connected by short chains with the arch heads of the beams, I I, and at the other end of these beams the motion is received from a small high-pressure steam-engine, through the crank, G G, and the connecting rods, H H.

The apparatus is connected with the up-cast shaft, A, by a culvert, B, which communicates both with the interior of the aërometers and the top chamber, the interior cylinders of masonry, D D, and the inlet valves, K K. The operation, then, of this machine is precisely that of a pump. When the pistons ascend they are filled with air, and at the same time

discharge the air out of the top chambers through the outlet valve, L L, and when they descend they discharge themselves through the outlet valves, L, and the top chambers are filled; the supply of air in both cases being drawn from the mine.

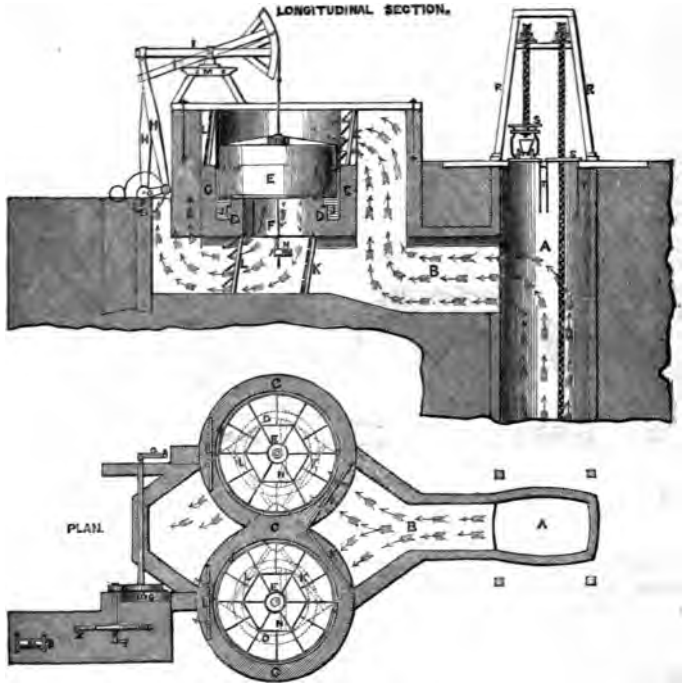


Fig. 46. Struve's Apparatus.

A. The up-cast pit.

B. A culvert, six feet by ten feet, connecting the up-cast pit with the ventilator.

C C. Two cylinders of masonry, ten feet interior diameter and seventeen feet high.

D D. Two interior cylinders of masonry, ten feet interior diameter, and seven feet six inches high. The space between the two cylinders, J, is filled with water seven feet deep, which prevents the air from escaping or being admitted except through the inlet or outlet valves.

E E. Two aërometers, sixteen feet in diameter, and seven feet high, made to balance each other, and to move vertically in the water by means of the guide rods in the centre.

F F. Rods working in guides, to give the pistons a steady motion, and to form a connexion by means of short chains with the arch heads of the beams.

G G. Two cranks placed at right angles to each other in a shaft connected with an engine.

H H. Two connecting rods, conveying the motion from the crank to the beams which work the aërometers.

I I. Two arch-headed beams.

K K K K. Four air ports, ten feet by seven feet six inches, fitted with valves for discharging the air into the atmosphere.

M M. The framing which supports the working beams, and also the whole weight of the aërometers.

N N. The beams supporting the guides for the rods to work through.

P P. The embankments formed from the cuttings of the foundations.

R. The framing of a pit for raising coal, showing the cover, S, raised by the wagon, and the platform of the wagon supplying its place; also the other cover, S, at rest on the other compartment of the pit, with the rope or chain working through it in order that the raising of coal may not interfere with the continuous current of air from the mine to the ventilator; and in order to prevent leakage, the tubes T T T are attached to the top of the pit, and the platform on which the wagon rests enters one of these tubes before the cover, S, is lifted.

Z. The engine-house, with a thirteen horse-power engine to work the machine.

One of the learned contributors to the "Edinburgh Review," in an article on Mortality in Trades and Professions, forcibly illustrates the importance of good ventilation in mines, and states, "his (the miner's) supply of oxygen is small; for in all probability the air supplied to him has to circulate many miles through the mine, and to pass over the excrementitious deposits of man and horse, and the decaying woodwork of the mine, ere it finally reaches him, in enfeebled streams, in his solitary working cell. Long deprivation of solar light, again, tends to impoverish his blood, to blanch him, in short, like vegetable products similarly deprived of the light of day. It is through their lungs, however, that the health of the miner is principally attacked. The air of a coal mine (such as it is) holds a vast amount of coal dust in mechanical suspension, and this, as a matter of course, is constantly passing into the lungs of the miner. The proof of this is the so-called 'black spit' of the collier, which, on being subjected to the microscope, is found to consist of mucus filled with finely-divided particles of coal. The permanent inhalation of such an atmosphere results in what is termed the 'black lung.' The breathing apparatus of the collier becomes clogged, in short, with coal dust, and after death it has the appearance of being dipped in ink. A writer who has lately investigated this singular pathological condition, thus gives his experience of two *post-mortem* examinations:—'In each case the black treacly fluid obtained by thus cutting the various portions of the lung (more especially the posterior and inferior portions of the lower lobes), and by splitting up, the bronchial tubes are evaporated to dryness, and the residuum being broken up and subjected to a red heat in a porcelain tube retort, behaved precisely as coal under similar circumstances, *i.e.*, it evolved a smoke-like gaseous product, which on being slightly condensed, deposited hydrosulphide of ammonium and coal tar, and being then purified burnt in all respects like the well-known compounds of the two carbides of hydrogen (common gas).'"

Although a chemist would object to the mode of testing for coal in this last-quoted experiment, as the animal matter was not first separated from the impalpable coal dust, and the products from both were therefore eliminated together during the destructive distillation, still there can be no doubt respecting the carbonaceous nature of this black treacly fluid.

"Dr. Gregory, of Edinburgh, many years since, by destructive analysis,

came to the same conclusion respecting the carbonaceous nature of this deposit. The presence of this foreign body in the lungs leads to the whole train of pulmonary diseases. Asthma, bronchitis, and pneumonia are but too frequent, and we are consequently not surprised to hear that the aggregate amount of sickness experienced by this class for the period of life from twenty to sixty, is ninety-five weeks, or sixty-seven per cent. more than the general average.

"It is estimated that the worst coal mines can be ventilated thoroughly at a cost of one penny per man per day, and that in well constructed furnaces the consumption of one ton of coals per day at the bottom of an up-cast shaft will enable each collier to cut one ton of coals more per day with the same amount of exertion. Such being the case, there can be no excuse for asphyxiating the miners wholesale. Those proprietors of mines who are only open to these breeches-pocket appeals, should know that it is their interest in a pecuniary sense to ventilate well, inasmuch as the preservative effect of pure air upon the wood brattices, which form so expensive an item in mining, effects a saving of eighty per cent."

With this digression on the important subject of ventilating mines, we return again to the descent of a coal mine, and resume the narrative from page 65, where we left off to explain the various methods employed to give the miner air. "After taking my seat on the bench for a few minutes, I soon recovered the use of my senses, and the first object of interest that I noticed was a sort of inner den or cave, from which there issued the usual odour of a stable; so I said to my guide, 'What! horses here?' 'Oh, yes, sir; nice little "gallusses,"* aint they?' And at that moment a sleek little nag, well groomed and cared for, came into view; and I soon found that the animal was detached for my special service, and that I was to go into the workings without the trouble of wading through the muddy channels on foot, in fact, to ride in front of a rolley or truck conveying empty baskets or corves to be refilled with coals. Before taking my seat, I was presented with a lump of clay and a miner's candle; and perhaps careful people may be desirous of learning what sort of candle it could be? Was it a six, or a twelve, or a long ten? No, it was one of those remarkable lilliputian candles from twenty to thirty to the pound; and the reason of this exemplary economy will be understood, when it is stated that the miners provide their own candles; the coal owners do not furnish them. The quantity of oil and candles consumed in the mines of the United Kingdom cannot be less than half a million of money in value; and it is only surprising that in safe mines—viz., in such as are free from fire damp, that coal gas is not more extensively employed. Some time ago, Mr. Wright read a most interesting paper before the Society of Civil Engineers, and quoted an instance where the cost of lighting a mine had been reduced from about 800*l.* to 400*l.* per annum by the use of coal

* Gallusses, a corruption of the word Galloway, being a hardy little horse first bred at Galloway, in Scotland.

gas; and as it burns without producing soot or those disagreeable empyreumatic odours arising from the imperfect combustion of tallow and oil, and at the same time affords a better light, it will no doubt be gradually substituted for them. Having taken my seat in front of the corves on the rolley, away we went for something like three quarters of a mile into the workings, for this mine is somewhat ancient, and has been worked since the time of Queen Elizabeth. Either I did not hold my candle properly, or we moved too quickly, for it soon guttered away, and deposited an ample greasy hæmorrhage in my hand, and at last, receiving a drop of water from the roof, it sputtered angrily, and burnt dimmer than before. I cannot say that at any time we came to a full stop, but occasionally we perpetrated a sort of comma, or moderation of our pace, in order to allow the little trapper boy time to open his door.

Fig. 47. Trapper Boy.

These doors are used for the purpose of maintaining the continuity of the ventilating currents of air, because if the latter was allowed to make its way at random through the workings, some parts would have a perfect hurricane of wind, whilst in others the air would stagnate and suffocate the persons engaged in the mine.

"The 'trapper' boy's employment is his first dreary apprenticeship in the coal mine; and if he can bear that, he is not likely to be timid afterwards. There they sit for hours in the dark, they must not stir from their posts, for fear of being lost; indeed, there was a case of this kind in a Welsh pit: a little trapper boy strayed away from his door,

and was lost for three days; the lad stated afterwards, that he frequently made his way to the back of the place where the colliers were at work, and even heard the sound of their picks, he screamed and roared, but it was of no use, they could not hear him, and it was only by accident he providentially struck upon the right path, and made his way in a wretched condition to the bottom of the coal-pit shaft. The pitmen will tell you, that after the first few hours, the constant question of the trapper boy to those who pass him is, 'Will it soon be time to cry Kenna mon?' alluding to a cry which is shouted down the shaft when it is time to leave off work. If personal friends go through his doorway, he will beg a light with a coaxing 'Gie us a loo, mon,' for his mother only furnishes him with two of the peculiar dips already alluded to: viz., one to light him to his door, and another to light him to the pit's mouth after his 'shift of work' is over; but, as before stated, this must be regarded as the apprenticeship to coal-pit work, and if the boy can get through this, he can do almost anything afterwards.

Fig. 48. The Crane Hoister.

"After proceeding a considerable distance on a tram-way, the little horse at last pulled up, and I found myself in a part of the pit which had been widened out so as to afford room for a crane, where I made the acquaintance of the crane hoister, whose duty it is to lift the cases of coal from the rolleys pushed by lads to those which are pulled by the horses. This lad is supposed to be better informed than his hard-working companions, as he has sufficient learning to enable him to chalk down upon a slate the number of corves that pass him. And here perhaps it may be asked—How do they distinguish between the idle and the industrious? or, rather, we ought to say, between the weak and the strong? And how can they tell who fills each corve with coal? The answer is very simple: each coal hewer attaches his own wooden label to the basket he fills; this is noted at the crane, and also at the pit's mouth, so that no man is likely to be defrauded of the just reward of his labour; moreover, the quality of the coal sent to 'bank' is strictly looked after, and the men are fined if they fill out their baskets with any rubbish or *débris* of the rocks they pass through.

"Having now dismounted from the truck, I proceeded on foot, in Indian file, after my guide, occasionally standing on one side to allow the rolleys pushed by half-naked lads to pass by; and here it may be said that the severe work of the mine commences. I have seen many kinds of labour, but never before witnessed such straining, pushing, and general activity; indeed, I could not help asking my companion whether they were doing extra work that day. 'No, sir, it's their regular work;' and such work as would put to shame any other that could possibly be thought of; and it is agreeable to know that now, in many of the first-

Fig. 49. The Putters at work.

class coal pits they are substituting Shetland ponies, whose hardy roughness is of course better suited to the fearful wear and tear than the poor human muscle, bone, and flesh of which our bodies are composed."

These lads are called putters, and have even amongst themselves grades of rank; for instance, the leader is called the "*headsman*," the second in dignity the "*half marrow*," and the third lad, who is generally attached to the rolley in front with a chain or rope, is called "*the foal*." It is curious to observe how nature illustrates science; these lads lose from six to eight pounds' weight during the eight hours' spell in the mine, and with their violent perspiration and increased respiration, lose a large amount of fatty matter, hence it is not surprising to hear that they generally prefer the fattest pork and bacon; and the lads especially enjoy now and then a great treat, called a "*singing hinney*," composed of flour and butter, or some other greasy material; this is cooked on a gridiron, and whilst being dressed the heat evaporates any watery particles therein contained with a sort of hissing or singing noise. It may be interesting at this point to speak of the temperature of mines in general, as instead of being cold they are usually warm, and the heat increases with the depth of the coal pit. Professor Graham says, in his "Elements of Chemistry"—"There can be no doubt of the existence in this globe of ours of a *central heat*. At a depth under the surface of the earth, not in general exceeding twenty feet, the thermometer is perfectly stationary, not being affected by the change of the seasons; but at greater depths the temperature progressively rises."

M. Cordier, to whom we are indebted for a most profound investigation of this interesting subject, considers the two conclusions to be established by all the observations on temperature which have been made at considerable depths:—1st. That below the stratum where the annual variations of the solar heat cease to be sensible, a notable increase of temperature takes place as we descend into the interior of the earth. 2nd. That a certain irregularity must be admitted in the distribution of the subterranean heat, which occasions the progressive increase of temperature to vary at different places.

Fifteen yards has been provisionally assumed as the average depth which corresponds to an increase of 1° Fahrenheit. This is about 116° for each mile. Admitting this rate of increase, we have at a depth of 30½ miles below the surface a temperature of 3500°, which would melt cast iron, and which is amply sufficient to melt the lavas, basalts, and other rocks, which have actually been erupted from below in a fluid state. But this central heat has long ceased to affect the surface of the earth. Fourier demonstrates, from the laws of conduction, that although the crust of the globe were of cast iron, heat would require myriads of years to be transmitted to the surface from a depth of one hundred and fifty miles. But the crust of the globe is actually composed of materials greatly inferior to cast iron in conducting power.

The temperature of the surface of the globe now depends upon the amount of heat which it receives from the sun, compared with the heat

radiated away from its surface into free space. There is reason to believe that no material change has occurred in the quantity of heat received from the sun during the historical epoch. The radiation from the surface of the earth has its limit in the temperature of the planetary space in which it moves, which Fourier deduces from calculation to lie between —58° and —76° Fahr., and which Schomberg, from a calculation on totally different principles, estimates at —58°·6; a close coincidence. This low temperature appears to be attained in the long absence of the sun during a polar winter, as Captain Parry found the thermometer to fall so low as —55° or —56° at Melville Island; and Captain Back has recorded a temperature, observed on the North American continent, so low as —70°. The temperature of the famous Monkwearmouth colliery, one of the deepest and perhaps worst ventilated mines in the United Kingdom (having only one bratticed shaft), stands at about 78° to 80° Fahr.; and in the workings, where the temperature is increased by the heat from the bodies of the men and their lamps, the thermometer ranges from 85° to 90° Fahr. The temperature of the water issuing from the Artesian well of Grenoble, 600 yards in depth, is 82° Fahr., being an increase of one degree for every 59 feet in depth.

The statement of the existence of an internal heat in the earth is curiously corroborated by the natural tar wells of Rangoon in Birmah. This empire contains more than 500 wells in a small district called Rainanghong. The soil there consists of a sandy clay, covering a thick bed of slate clay saturated with naphtha, under which is coal, as if a kind of natural distillation had proceeded from the coal below; and since petroleum contains paraffin, a product of the dry distillation of vegetable substances, it was inferred that this substance originated from the action of subterranean heat upon coal. According to our knowledge of the increase of temperature towards the interior of the earth, coal beds at a depth of about 8000 feet would possess a temperature of 212°; and we may suppose that this petroleum, or mineral tar, was distilled from such beds and condensed at higher points. But in this case the temperature of the soil impregnated by it in places where it occurs in large quantities, as in Asia, must long since have been raised to a nearly equal degree, which is, according to the observations made by Abiel, by no means the case.

On the western shores of the Caspian, in the country round Baku, upon the peninsula of Abscheran, a tract has been long known under the name of the "*Field of Fire*," which continually emits inflammable gas, while springs of naphtha and petroleum occur in the same vicinity. Abiel found the medium temperature of the soil of Abscheran to be 59° Fah., that of the naphtha 62°·5 to 66°, and that of the gas springs 68°·5; the gas therefore can only come from moderate depths. Upon the Schagdag, not far from the village of Kinalurghi, 7834 feet above the Caspian Sea, are found considerable exhalations of carburetted hydrogen gas (the *Eternal Fire* of the Schagdag), which stream directly out of clefts in sandstone alternating with slate. This burning gas is

never extinguished by atmospheric changes, and these, with other natural and eternal sources of fire originated, no doubt, the ancient faith of the Fire Worshippers.

The Rangoon tar is brought to this country in iron tanks, and some very important and practical results have been worked out from it at Price's Candle Factory, in the preparation of paraffin candles and Belmontine oil. There are three qualities of oil obtained: one like alcohol, is ignitable by wick only; the second is brown in colour, and useful for machinery and spindles, with the advantage of not corroding metals. The third is a detergent fluid, and will remove grease spots, without staining even delicate silks.

At Colebrookdale, in Shropshire, there is a naphtha spring rising from a coal seam. It likewise occurs at Amiano, in Parma, at Modena and Piacenza, near the Tegernsee, in Bavaria. Mineral tar occurs in Persia, France, and several other places.

Numerous experiments have confirmed the theory of Cardieu and others, that the temperature increases one degree of heat for about every fifteen yards, and the following results may be quoted as good examples, because they are obtained independent of the air, which must partake of the temperature of the bodies of the colliers and their burning lamps or candles.

	Fahrenheit.
Whitehaven.—Spring water at surface	49°
Ditto at 480 feet	60
Ratio from surface, one degree for 44 feet.	
Workington.—Spring at surface	48
Ditto at 504 feet	60
Ratio from surface, one degree for 42 feet.	
Percy Main Colliery (Tyne).—Mean temperature at surface	49
Ditto at a depth of 900 feet	70
Ratio from surface, one degree for 43 feet.	
Jarrow Colliery (Tyne).—Surface assumed	49·5
Water at 882 feet deep . . .	68
Ratio from surface, one degree for 48 feet.	
Killingworth Colliery (Tyne).—Surface assumed	48
Water at 1200 feet depth .	74
Ratio from surface, one degree for 46 feet.	

In trudging through the galleries of a coal pit, the visitor becomes hot and feverish with excitement, until a copious perspiration breaks out and relieves the sufferer; he then feels as I did, able to finish his work and proceed to the actual spot where the men are digging or hewing out the coal.

The cut offers some idea of the numerous tiring and almost painful postures the miners are obliged to assume; kneeling, stooping, and lying down, and great activity is required to change the position rapidly, in order to get at the coal; and when the limbs have become stiffened

with age and exposure to the vicissitudes of mining life, the daily earnings are much reduced, and whilst some men may earn four, others will

Fig. 50. Various Positions assumed by the Hewers in digging at the Coal.

only get three shillings per diem. There is, however, some consolation left to the men—viz., in the fact that they have now arrived (so far as the hard work is concerned) at the very tiptop of the profession. The writer (already alluded to) on Mortality in Trades and Professions, says, "Of these artisans, exposed to irritating dust, probably miners take the second place after the miserable Sheffield dry

grinders. If we investigate the condition of these men, we are immediately struck with the lamentable conditions under which they labour, and astonished at the endurance and patience with which they submit to toil, to which that of the well-fed, well-housed *felon* is pleasant pastime. There are at present upwards of 300,000 human beings acting the part of gnomes (those imaginary beings who were supposed to inhabit the interior of the earth), for the good of the community at large, entering day by day into the bowels of the earth, and emerging in the evening. Of human life they see as little as the train of black ants we watch emerging from their holes in the ground. Yet the miner is the industrial *Atlas* of England. Were he to cease to labour, this busy hive of men would speedily be hushed, and the giant limbs of machinery, which now do the drudgery of the world, become as still as the enchanted garden of the fairy tale ere the advent of the prince. Without the coal and the iron, the copper and the tin, they toilfully evolve from vast depths, England would be but a third-rate power. In many pits in the West of England the seams of coal are not more than twenty or twenty-five inches thick; and inasmuch as the object of the worker is to remove the coal with as little as possible of the surrounding soil, he often drives his working to a considerable distance through an aperture not more than, and often not so much as, two feet high. If our adult reader will condescend to squat himself on the floor *à la Turque*, say under the dining-table, for instance, and then picture to himself the inconvenience of picking with an axe the under side of the prandial mahogany for twelve hours, he will obtain some slight idea of the muscular knot into which the poor collier has to tie himself for the whole term of his working life, having to use violent exertion throughout. Can it be wondered at that, under such circumstances, the Apollo-like form of man becomes permanently twisted and bent, like the gnarled root of an oak that has been doubled up in the fissure of some rock? If we look at a collier, we see instantly that his back is curved, his legs bowed, and the extensor muscles of his calves withered through long disease. He has knotted himself so long that the erect position of his race becomes a punishment to him. It is credibly related that a number of colliers having been sentenced to imprisonment in Wakefield jail, with hard labour, the only complaint they made was, that they were *obliged*, whilst at work, *to keep* the *ordinary posture* of rational creatures."

Working as these men do, in constant fear of death, it is no wonder that they are somewhat superstitious, and firmly believe in bad spirits and omens. Should a collier meet a woman whilst going to his work at any very early hour in the morning, such as two or three o'clock, he would consider that circumstance as a bad omen, and would turn back from his work; or if any white animal, such as a rabbit or a cat, happen to cross his path, he would not risk his life that day in the coal pit. Superstition is not confined only to the poor miners; one of the most learned of men never considered his affairs would go quite smoothly during the day unless he trod upon a particular stone in Bolt-court.

With respect to the labour of the collier, some idea may be formed

of its severity by obtaining the opinion of other hard-working men. It is stated that during the temporary strike of the "coal whippers" (the men who discharge the cargoes of the colliers or coal brigs into barges on the Thames), a benevolent gentleman thought he could employ some of the fine stalwart men who were thrown out of work, by sending them down to the coal pits in the North, and, by way of trial, three strong, able-bodied men were selected and forwarded, carriage paid, to their destination. They did not, however, imitate the example of the great Cæsar—they went, they saw, but did not conquer; indeed it would appear they were disgusted at the notion of any one supposing that human beings—"Christians"—could be asked to do such work, and vanished from the scene without condescending to offer any explanation of their conduct to the kind gentleman who imagined he had discovered a new market for their labour; hence "coal whippers" thought their work quite easy as compared with that of the "coal hewers." In certain coal districts with small workings, as in some parts of Staffordshire, the mining population displays great and lamentable ignorance, with all the poverty and squalor of crowded dwellings; but in the best-regulated and larger coal-pit districts of the North, the collier is a sensible and self-respecting man, keeping a good cottage over his head and taking care of his wife and children, the latter being clean and flaxen-haired; whilst the "gude wife" shows her appreciation of her lord's care by cramming the cot with the largest and most Brobdignagian furniture she can procure; and it is said that there is quite a competition in a first-class "rookery," or assemblage of miners' cottages, amongst the matrons for the possession of the best household gods. A clever observer and writer in a Northern paper says:—

"The pitman is not the mere wretch that haunts a refined imagination. The influence of his dark environments, and of a life under the unique conditions of a deep Northumbrian mine, displays itself less in his physical than it does in his mental malformation. The village attached to a colliery, or a 'colliers' row,' as it is called, may not have an attractive exterior—it seldom has—but it reverses the description of a whited sepulchre: it is dingy enough without, but enter the humble mansion, and you find it the very picture of cleanliness and comfort. You will find an eight-day clock; you will find a shining table turned up against the wall; you will find a four-post bedstead and half-a-dozen excellent chairs; and, above all, you will find in the mistress of the house a love of external purity almost amounting to a passion. At the same time you will discover a certain barrenness of imagination in the arrangements, a tendency to assume stereotypic forms, a monotony and uniformity in the mode of fitting out those little mansions, which is not an agreeable, because not a healthy feature. You observe, as a general rule, no indication whatever of any individual fancies. Not a soul in the place seems to have a taste of his own. The interior of one pitman's cottage is as like another as the hexagonal cells of a honeycomb. There is in each the same four-post bedstead, the same shiny table against the wall, the same eight-day clock, and the

same six stout chairs. With an obvious determination to gratify a sense of general comfort, there is no more effort apparently to meet individual tastes than if the human family had been cast in the same unvarying mould of propensity, desire, and aptitude. This, we repeat, is not a wholesome characteristic, but it is surely far enough removed from the misery which has been depicted. Cleanliness, according to John Wesley, is to be ranked as next to godliness. There is not much godliness in the pit; but no artisan's wife alive is more careful of her husband's appearance, and of the appearance of the house he has to come to, than she who waits with tub and soap the approach of her grimy goodman. A story is told of a pitman in one of the neighbouring villages, who wanted to lay up a sovereign unknown to his wife, in anticipation of a coming cock-fight; but where to store it was the rub. At length it occurred to him that by putting it between one of the bedposts and the floor, so that the post would rest upon it, he might put detection at defiance. The day of the fight arrived, and John, sending his wife out on a message, proceeded to raise the bedpost and draw out the hidden coin. Out it came shining and safe, but he could scarcely believe his eyes: it seemed to be only a half-sovereign. 'My conscience,' he said, 'how it has shrunk!' The fact was, Jean had been accustomed to whisk out the dust from recesses which no broom would enter, by means of a goose's wing, and her attention was one day rewarded by whisking a sovereign from under the bedpost, and, deeming she had a right to the half of it, for whatever purpose it had been deposited there, she took the precaution to substitute the smaller coin, which John invested in the chances of the cock-fight. Unfortunately, we fear, the cock-fight, or rather the habit of mind which seeks its gratification in such a display, is equally characteristic of the pitman. He is not uncomfortable, but he is sometimes very wicked. England may be said to have two populations, a terrene and a subterranean; and the annals of crime show that the begrimed myriads burrowing beneath our feet, among the crystallized remains of a forest older than the ichthyosaurus, live and move in a moral darkness of which the darkness of the pit is but the symbol. For there is no denying that, in the scale of criminality, a mining population does stand unenviably high; and they who owe their wealth to the toils and the drudgery and the danger-defying labours of the human gnome will be the first to acknowledge and lament, and the first also, we hope, in their efforts to abate, the deplorable thing we mention. Northumberland ranks among the most criminal counties in England, and in this rank it stands actually as high as fifth,—more crime being committed in Middlesex, Lancashire, Surrey, and Warwick alone.

"It was laid down at a recent meeting of the Social Science Association that the amount of crime is in a direct ratio to the density of a population; which, indeed, is only saying that most crime will occur where the criminal has most chances of escape, and that where the greatest number of persons of every character is assembled, there will also be the greatest number of bad characters. But Northumberland is an exception to the

rule. Northumberland is less dense in population than other counties less criminal. Several counties more compactly inhabited produce a lighter calendar; and our place in the criminal scale may be safely set down, we imagine, to the fact of our possessing a large and growing underground population. But when the subject is fairly considered, the rule that criminality is in direct proportion to the density of the population in which it occurs, is as much in harmony with the circumstances of a mining as with the circumstances of a metropolitan population. To a large extent the two classes come under the same category, for that temptation to crime which arises from the facility of escape, operates no less on the collier when he finds himself in the open air, than on the London thief in the neighbourhood of one of his favourite alleys. The one believes he has only to plunge into the pit, the other believes that he has only to plunge into the slum, in order to defy pursuit. To this influence must in part be attributed the excess of criminality predicated of our mining population. But the density of a mining population increases that influence by increasing the chances of escape still farther; and the population of Northumberland is rapidly increasing in density. The population of England and Wales, taken over all, increased during the decade ending 1851 at the rate of thirteen per cent.; but in the mineral counties of England, which are the most criminal counties, and in Glamorganshire, in Wales, which has the same physical and moral characteristics, the increase amounted to nineteen per cent. upon the preceding enumeration. Of that increase Northumberland has more than had its share. Here, then, in the condition of a mining population, we have almost every circumstance meeting favourable to the genesis of crime. There is density of population, facility of escape, gross and prevailing ignorance; but there is not that lowness of physical comfort which superficial observers imagine. Wages are good, work is abundant, and masters have had too many fearful warnings of the readiness of their men to strike, to be very unreasonable or exacting. Though that element of criminality, however, so far as we have been able to observe directly, is in a great measure wanting, especially in the North of England, its absence is more than made up for by another important circumstance characteristic of the life of a pitman, for a tendency to excess is greatly exaggerated by that recklessness of consequences incident to all peculiarly precarious occupations. It is never more difficult to keep the crew of a vessel back from the spirit-stores than when the vessel is on fire and the dare-devils know that the flames will soon be at the powder-casks. Much of the recklessness which seems almost constitutional in a seaman is undoubtedly due to the continual possibility of the occurrence of some such accident, and to the continual occurrence of accidents in which lives are extensively lost. The same influence is always at work in a mine. Let us eat and drink, for to-morrow some one will be lighting his pipe at a Davy, and we shall all be blown to atoms. Let us eat and drink, for to-morrow the roof of the pit will be falling in, and we shall all be crushed to a jelly. Let us eat and drink, for to-morrow the rope by

which we descend will be breaking, and we shall be gathered up in bloody fragments at the bottom. The exposure of a pitman to this continual but uncertain danger naturally results in an uncalculating and reckless temper—a recklessness which does not display itself merely in a course of abandonment to pleasure, but in doing at once and with all his might whatever his hand findeth to do, whether it may happen to be a violation of the law or not."

If it be expedient, in these days of advancement in all civilized arts, to discuss the question of the amelioration of the condition of the "pitman," there could be no question about the absolute necessity of a searching inquiry into that of the poor "pit-women," who were formerly induced and expected to work in those dreary regions. The debased condition of these poor creatures can be well appreciated when we read the evidence respecting the "Yorkshire Coal-fields of the West Riding." "Girls from *five* to *eighteen* perform all the work of *boys*. There is no distinction whatever

Fig. 51. Susan Pitchforth.—"I would rather set cards, or do anything else, than work in pit. I have one sister going of fourteen; she works with me."

in their coming up the shaft or going down. In the mode of hurrying or thrusting, in the weights of the corves, or in the distances they are hurried—in wages or dress. Indeed, it is impossible to distinguish, either in the darkness of the gates (galleries of mines) in which they labour, or in the cabins before the broad light of day, an atom of difference between one *sex* and the other. It is not my intention to indulge in any display of fine feelings in directing your attention to their employment in these dens of darkness, but I should be a traitor to my countrywomen if I did not by every means in my power attempt to excite in you, and through you, a desire to rescue them from a state of moral degradation and suffering to which they are doomed, and that, too, it may be affirmed, much against their inclination."

It would be tedious to quote all the illustrations of the evil effects of employing women in coal pits; their cruel degradation must be evident from the next cut. Thus, with respect to the poor creature crawling on hands and knees, with that rude coal-box without wheels attached to her waist with a chain, the commissioner stated that her sister was doing

Fig. 52. Women at Work.

the same kind of work in a coal pit, and that she was positively *beautiful*. (Fig. 52.)

Again, the poor old woman whose duty it was to carry the creel, or basket, on her head from the bottom to the top of the coal shaft, up a rickety ladder or rude staircase, when interrogated, replied with great bitterness, and said "she wished the back of the first woman had been broken who first undertook to carry the coals, for it was not work for women folk;" and it is pleasing to know that very soon after these statements were published, such were the efforts made in both Houses of Parliament, and especially by Lord Ashley, now the Earl of Shaftesbury, that an act was passed in the reign of our beloved Queen Victoria, whom God long preserve, which abolished for ever the labour of women in coal mines, and said that no children for the future should work in coal pits who were of a less age than ten years. Before the act was passed, it was stated that poor little things from three to five to seven years were actually employed to pick up coal in the pits, for the sake of the miserable pittance their tender strength could earn. It is indeed satisfactory to know that this blot on the industrial records of Great Britain is now wiped out.

EXCAVATION OF THE COAL.

It is not usual to remove the whole of a seam of coal, as the miners burrow into the earth, but to divide and intersect it by what are variously termed "partings," "backs," "faces," "cutters," and "ends." Besides the chief partings at the roof and floor of the coal seam, there

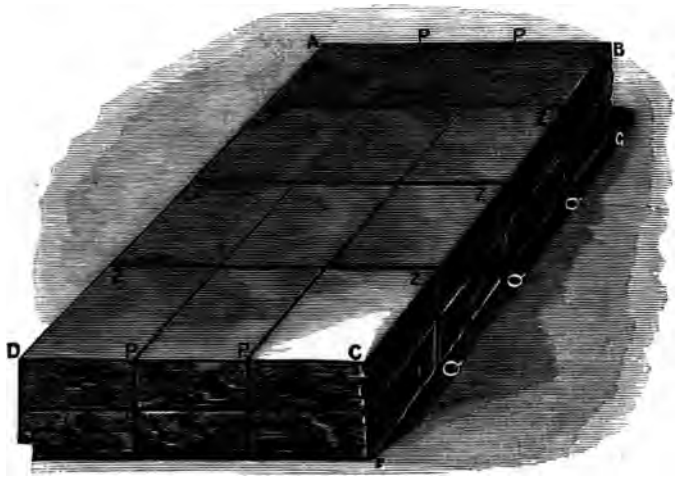


Fig. 53. Method of excavating Coal.

are intermediate lines of parting, or places of cleavage, parallel to the chief partings.

The letters A, B, C, D, E, F, G (Fig. 53), represent a mass of coal, being a portion of a regular coal seam, and they are the chief partings at the roof and flooring respectively; Q, Q, Q, the intermediate "partings," or planes of cleavage; Z Z, Z Z, Z Z, the "backs;" P P, P P, the cutters. It thus appears that a bed of coal, according to the number of these planes of cleavage, may be broken or subdivided into solid cubical blocks. The most common method of working the coal is by "post and stall," or "pillars and rooms;" by which plan a certain quantity of the coal is left in the pit to support the roof, and these pillars are subsequently removed, when the whole coal field has been worked out in this form.

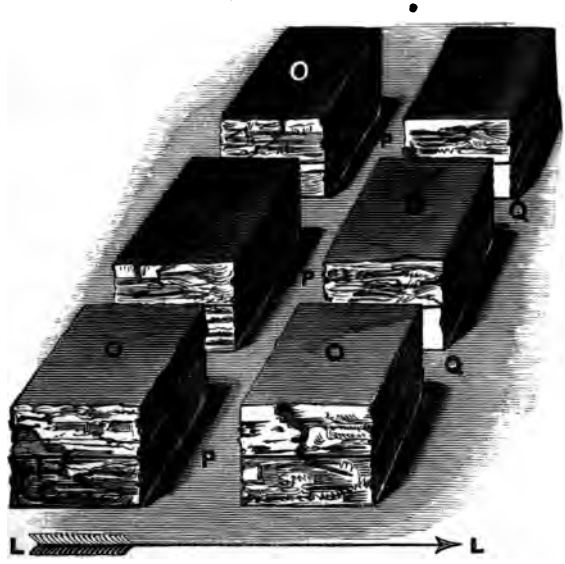


Fig. 54. "Post and Stall System."

After driving the main levels in opposite directions upon the engine-shaft, narrow mines, or galleries, called "bays," are driven out of the main levels at regular intervals, in the direction of the rise, at right angles to the backs. "Cross-roads," or "cut-thro's," are then driven at right angles to them at every five or six yards—thus, in Fig. 54, L L represents the main level; O, O, O, O, O, O, the pillars of coal supporting the roof; P P P, the gallery; Q, Q, the cut-thro's. The galleries are

not usually at right angles to the main levels, but sometimes meet them in an acute angle, as in the ground-plan.

Mr. Kennedy has compared the post and stall method to a subterranean town, with its numberless streets and alleys. The blocks or pillars of coal left standing correspond with the houses, whilst the galleries, or portions removed, are analogous to the streets.

After the coal has been removed in the manner described, the colliers then return, as it were, upon their path, and proceed to remove the supporting pillars; but by this time, probably, what is called "a creep,"

Fig 55. A Creep, and Cause of Thurst.

has taken place in certain parts of the mine, and the floor gradually rises between the supporting pillars, by the superincumbent pressure of the earth, and fills the space from which the coal was excavated (Fig. 55).

1 shows the state of creep when ready to commence the working of the crept pillars; 2, the first operation, or partial working of crept pillars; 3, the second operation, or complete working of crept pillars, where the roof is supported by wooden props and juds; and as they are very economical in a coal pit, and will not leave a stick behind if they can help it, they gradually draw away the props, and then, perhaps in a few hours, days, weeks, or months, down falls the earth in great avalanches, filling up the hollow space in a partial and irregular manner, and forming at 4 what is termed "the goaf," being those portions of a mine which have been worked out or deserted; and it is (as will be presently noticed) from these portions of the mine that the "fire-damp" issues which does so much damage to life and property.

When a coal field has been completely worked out, and the props re-

moved, a gradual subsidence of the earth takes place, which the miners call a "thurst" after a creep.

Fig. 56. A Thurst after a District of Crept Pillars is completely wrought off.

The effect of the sinking of the earth is sometimes very apparent on the cottages and houses of those who live above the exhausted coal fields; and as the earth becomes slightly concave, they all partake of the angle, and the sinking of the door posts and window frames, with cracks in the walls, show clearly the result of the underground tunnelling.

Bills are filed in Chancery for injunctions to restrain persons from working mines under houses, and also from working any mines under land adjacent thereto, in such manner as to cause damage or injury to the foundations of the houses. As to the people who live in these tumble-down dwellings, they, "like the unfortunate eels," become quite used to the effects of these artificial earthquakes, and will not condescend to turn out of their houses until they are just on the point of falling and crushing them in the ruins.

There are three modifications of the "post and stall" system prac-

Fig. 57. Ground-plan of the Shropshire Method of "Long Work." The face where the men are at work is drawn in perspective to assist the explanation.

tised with seams of coal of every thickness. With the coals which are only some six or seven feet thick, "the long work wall," or Shropshire method, is pursued (Fig. 57). By this system no pillars are left, but all the coal is taken out progressively as the workings advance; the roof is supported by underposts near the face at which all the men work in a line. As the workings are carried forward, the posts are withdrawn, and the superincumbent strata are allowed to fall in at the heels of the miners.

In the cut Fig. 57, A represents the engine-pit and down-cast; B, the up-cast or cross-pit. The shaded portions represent the coal seam. The white part marked "Goaf" up to the irregular line, represents that portion of the seam which has been exhausted, and of which the roof has fallen in; the small circles represent the underposts which support the roof at the faces where the men are at work, and the arrows represent the course of the air from the down-cast to the up-cast.

In the Bristol coal district colliers work seams of coal as low as nine inches thick. In the latter case, at least sixteen or eighteen inches must be excavated to allow the men to work in the recumbent position, and on their sides, the other seven or nine inches being shale or fireclay. The collier holes, or works under the coal, with his elbow resting on the inside of his knee.

On the other hand, there is the great Dudley seam of coal, which is thirty feet thick (Fig. 57); and here, of course, the men work in greater comfort. It is usual for the pitmen to contract to remove so many cubic yards, and they commence by first digging or holing away the base of the cube, which is then propped up with timber; in the next place, they cut away the sides and top, leaving only the back, which is finally charged with gunpowder, and connected with a slow match. On a proper signal being given, all the men in its vicinity remove to safe quarters, the mine explodes, and down falls the great cubical mass of coal, which is soon shovelled off into corves or tubs, and conveyed to the pit's mouth.

During an imaginary walk through the coal pit I have said nothing, as yet, respecting the drainage of the subterranean works. Considerable practice and skill are required to select the right portion of the coal field to which all the water will fall, so that, as the workings proceed, they may not be incommoded. Hence, the shaft is not only completed to the coal, but is continued further downwards, as a well, or "sump," to provide "standage," or reservoir room, for the collection of the water. In some of the Shropshire pits I have seen large tubs used with a valve at the bottom, which are let down alternately with the empty "pyches" or frame boxes for the coals. The valve is forced open as the tub enters the "sump," and the water flows in; the tub is now lifted to the pit's mouth, when the pressure of the water shuts the valve, which is subsequently opened by a lever at the top of the shaft, and the water passes away by a surface drain. It shows the utter want of caution in the pitmen to see half-a-dozen of them come up, perhaps 300 yards, only standing upon the edge of one of the large tubs full of water, and holding on by the chain.

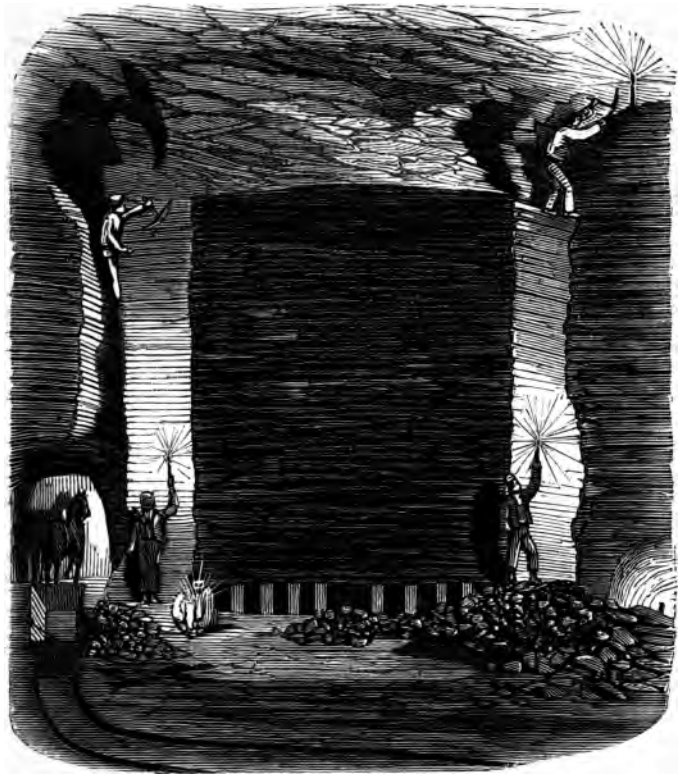


Fig. 58. The working of the great Dudley thirty-feet Seam of Coal.

In some of the mines it is found to be advantageous to carry out "driftings," or spaces dug out in the stone or coal to contain a week's drainage, or more; so that, in case of any sudden increase of water, they may have timely notice, and thus prevent accidents. Before the general employment of the steam engine, both coal and water were raised by horses; afterwards water-wheels were erected; and, in 1708, windmills were built for the same purpose. A majority of the mines yield large quantities of water; some have been known to yield as much as 2000, or even 3000 gallons per minute from very deep springs. Force-pumps, worked by powerful steam engines, are kept constantly

at work, both by night and by day; but as this part of the subject belongs especially to the details of the mining engineer, we shall not pursue it further here, except to state that the arrangement and working of the pumps is a part of the regular duty of a coal pit which demands constant care and attention, and is one of the heaviest expenses the coal owner has to contend against. Sometimes the unequal contest is given up, and a new shaft abandoned on account of the enormous cost of keeping it free from water. On the way back to the pit's mouth the water may be noticed ever flowing towards the "sump." And now, having once more arrived at the shaft we started from, I take my place in the empty corve, and again return to *terra firma*. A coal pit, no doubt, is a very interesting place to visit once or twice in the course of one's life; but the satisfaction is something akin to travelling in fast trains—we are glad to make use of them, but more delighted to step out of the carriage.

FIRE-DAMP.

In our journey through the coal pit we have alluded to some of the dangers, but said little or nothing about that most fiery trial to which the poor collier is subjected in many of the Newcastle mines, called "fire-damp." However good the general system of ventilation may be in a mine, unforeseen accidents will happen at any time. A sudden invasion of this combustible gas, disengaged by the fall of a mass of rubbish in the goaf, or of a quantity of coal in the workings, may meet the collier, who is working, perhaps imprudently, with a naked candle, and an explosion follows, which crowds the pit's mouth with a wailing multitude of newly-made widows and orphans. The "Edinburgh Review" says that upwards of 1500 lives are annually lost, and not less than 10,000 accidents in the same period testify to the dangerous nature of the miner's occupation. It is humiliating to know that England is yet far behind Continental nations in her methods of preventing these dreadful catastrophes. Mr. Mackworth, in his lecture at the Society of Arts, stated that the mortality from accidents was in the coal mines of

Prussia	1·89	killed	per 1000	per annum.
Belgium	2·8	„	„	„
England	4·5	„	„	„
Staffordshire	7·3	„	„	„

Fire-damp is not a definite chemical compound, but a mixture of various gases, and explodes only when mixed with a certain proportion of air; by itself the gas is simply combustible, like ordinary coal gas, and burns without detonation. The combustible gases from coal pits have been frequently analysed, and the following analyses by Bischoff and Graham afford a correct statement of the constitution of the gas which issues from a coal-blaze or blower:—

	Bischoff.			Th. Graham.	
	I.	II.	III.	IV.	V.
Carburetted hydrogen gas	83·08	91·36	79·10	94·2	82·5
Olefiant gas	1·98	6·32	16·11	—	—
Oxygen gas	—	—	—	1·3	1·0
Nitrogen gas	14·94	2·32	4·79	4·5	16·5
	100·00	100·00	100·00	100·00	100·00

The chief constituent of all pit gases is carburetted hydrogen, sometimes mixed with small quantities of olefiant gas and carbonic-acid gas. Nitrogen seems to be invariably present. It cannot be derived, says Bischoff, from atmospheric air in those instances in which it comes with force from fissures, but is no doubt a product of the decomposition of organic substances, most probably of the coal itself. The similarity of the pit gases to marsh gas is much in favour of the view that such is the origin of the nitrogen.

Light carburetted hydrogen is synonymous with marsh gas, fire-damp, and consists of C_2, H_4.

C_2, Carbon	12
H_4, Hydrogen	4
	16

The equivalent or combining proportion is 16, and the specific gravity 559·6, air being 1000.

This dangerous gas is liable to issue at any moment during the work of the coal-hewer, who may suddenly strike his pick into a cavity where the fire-damp has been pent up for ages. It rushes out with great violence, and is then termed "a blower." If the ventilation is good, and the men are working with safety lamps, little or no danger may be apprehended; but if naked candles are used, and the current of air in the mine is sluggish, the mixture of fire-damp and air accumulates to a remarkable extent; and the train being fired at some point, the whole explodes with fearful violence, blowing everything before it. Those who have visited pits after one of these calamities, state that the wood work is broken and splintered like twigs in the hand of a child, and living beings are projected bodily through frameworks of wood just as if they were hard, solid, and inanimate substances. The destruction of life, as it were in a moment, is frightful, one or two hundred lives being sometimes lost on these occasions. Science, however, steps in here, and clearly indicates that such calamities may be prevented—first, by good ventilation; second, by the use of safety lamps.

Having already alluded to the important subject of ventilation, which bears the same relation to the safe and successful working of a coal pit as drainage does in agriculture, some space may now be devoted to that valuable instrument called the safety lamp, with a brief digest of those

admirable experiments made by Sir Humphry Davy which led to its construction.

An opinion prevails amongst the "Newcastle folks" that Geordie Stephenson invented the safety lamp before Davy produced his, because the former was seen on one occasion observing "*that the flame of the candle did not pass through the small apertures of the latticed fender, and gathering from this fact the rude idea of a safety lamp;*" and further, that he actually constructed and tried his lamp at Killingworth Colliery before any other person had tested one under similar circumstances. In 1818 this opinion of the services of George Stephenson took a tangible and demonstrative form, in the shape of a silver tankard containing one thousand guineas, which were presented to him in the Assembly Rooms at Newcastle, as the "discoverer of the safety lamp." In May, 1818, Sir H. Davy collected and published, in a connected form, all the papers that he had written on this subject; and it must be evident from the originality of his experiments that he required no borrowed genius, that the ideas he worked out were his own, and that Stephenson and Davy must have been independent labourers in the same field, probably arriving at similar results by different means, just as Daguerre and Talbot, in the art of photography, reached the same goal by entirely distinct paths.

Sir H. Davy says, "When I first turned my attention particularly to the subject [accidents from fire-damp], which was in August, 1815, in consequence of a letter from the Rev. Dr. Gray, there appeared very little hope of finding an efficacious remedy. The resources of modern chemical science had been fully applied in ventilation, in the improved plans of Mr. Buddle; the comparative lightness of the fire-damp was well understood, every precaution was taken to preserve the communications open; and the currents of air were promoted or occasioned, not only by furnaces, but likewise by air pumps and steam apparatus. Sir James Lowther had observed early in the last century that the fire-damp in its usual form was not inflammable by sparks from flint or steel; and a person in his employment had invented a mill for giving light by the collision of flint and steel (Fig. 59). *This was the only instrument except common candles* employed in the dangerous parts of the British collieries. Yet instances of explosion have been known from the steel mill, and it required manual labour for its use. In Flanders, amadou, or fungus tinder, had been occasionally employed in dangerous parts of the mine; but the light yielded by this substance was much too feeble to be used for working the mines, and only enabled the miners to find their way for particular occasions. M. de Humboldt, the justly celebrated philosophical traveller, in 1796 conceived and executed the plan of a lamp* for giving light in mines where a common candle would not burn or produce explosion; but it was founded on the principle of entire insulation from the air, and could burn only for a short time till the air contained within it was exhausted.

* Journal des Mines, tom. viii. p. 839.

"A lamp upon a plan similar as to insulation was contrived by Dr. Clanny in 1813; but he supplied his light with air from the mine through water by bellows, and it went out in explosive atmospheres,

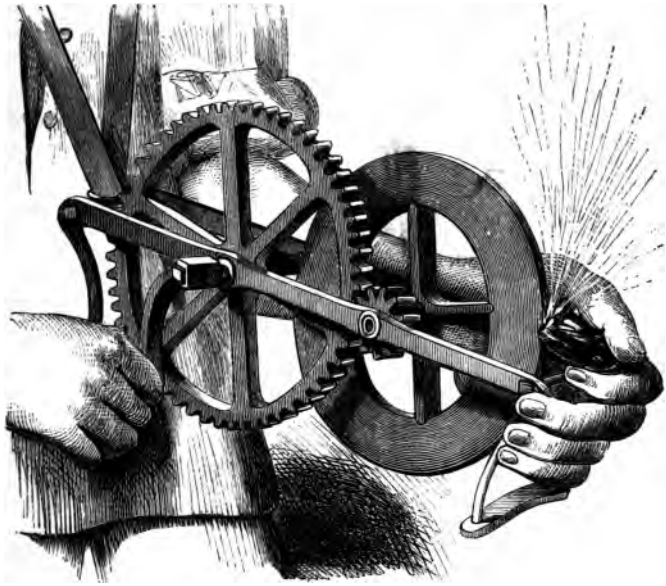


Fig. 59. The Steel Mill for giving Light in Coal Pits. The mill is attached to the waist of a boy, who holds the flint in one hand against the steel wheel, which is rapidly rotated by the other hand.

and, to be employed, required to be worked by hand or by machinery; and neither M. de Humboldt's lamps or Dr. Clanny's had, for obvious reasons, I believe, ever been used in coal mining.

"The great object—one rather to be *ardently desired* than *confidently expected*—was to find a light which, at the same time that it enabled the miner to work with security in explosive atmospheres, should likewise consume the fire-damp.

"Having learnt from Mr. Buddle the degree of light required for the common operation of the workmen, I made several experiments with the hope of obtaining such a light without active inflammation. I tried Kunckel's, Canton's, and Baldwin's phosphorus, and likewise the electrical light, in close vessels; but without success."

Kunckel's phosphorus is the element obtained from phosphoric acid, and used extensively in the manufacture of lucifer-matches. When exposed to air, phosphorus gives out light in consequence of the slow oxidation of its surface.

Canton's phosphorus is made by calcining oyster-shells in the open fire for half an hour; after which, the whitest and largest pieces are selected, mixed with about one-third their weight of flowers of sulphur, pressed into a crucible with a closely-luted cover, and heated red hot for an hour. When the crucible has become quite cold, its contents are turned out, and the whitest pieces selected for use.

Baldwin's phosphorus is prepared by melting nitrate of lime in a crucible or ladle for about ten minutes; it is then poured into an iron pot, or mould, previously heated, and has the property, like Canton's phosphorus, of absorbing light when exposed to the sun, and emitting it when taken into a darkened room.

The electric light is that obtained when two pieces of hard carbon, in connexion with a powerful voltaic battery, are brought in contact with each other.

Sir Humphry Davy further adds: "I had a lamp made with two valves, which closed in atmospheres contaminated with fire-damp by the increased heat of the flame produced by the combustion of the gas; but this lamp could not be used in an explosive atmosphere. It will be unnecessary to dwell upon preliminary and unsuccessful attempts, and I shall proceed to describe the *origin* and *progress* of those investigations which led me to the discovery of the principles by which explosion and flame may be arrested and regulated; and by means of which the miner is not only able to subdue and control, but likewise to render useful his most dangerous enemy.

"I first began with a minute chemical examination of the substance with which I had to contend. The analysis of various specimens of fire-damp showed me that the pure inflammable part of it was light carburetted hydrogen, as Dr. Henry had before stated, hydrogen, or pure inflammable air combined with charcoal or carbon. I made numerous experiments on the circumstances under which it explodes, and the degree of its inflammability. I found that it required to be mixed with very large quantities of atmospheric air to produce explosion; even when mixed with three or nearly four times its bulk of air it burnt quietly in the atmosphere, and extinguished a taper. When mixed with between five and six times its volume of air, it exploded feebly; it exploded with most energy when mixed with seven or eight times its volume of air; and mixtures of fire-damp and air retained their explosive power when the proportions were one of gas to fourteen of air. When the air was in large quantity, the flame of a taper was merely enlarged in the mixture; an effect which was still perceived in thirty parts of air to one of gas."

These original experiments of Sir H. Davy may be illustrated in a simple manner by filling a bladder with coal-gas and passing some gas from it into a graduated bottle filled with water. When half-filled with

gas, the bottle may be stoppered and removed from the pneumatic trough, and on taking out the stopper again, the water left in the bottle falls out and atmospheric air takes its place. After the gases have been well mixed by shaking the bottle, a lighted taper may be applied, when it will be found that the mixture burns with a feeble blue flame, but does not explode. On the other hand, if the bottle is graduated into eight parts, and one part only is filled with coal gas, whilst the remaining seven parts of water are displaced by air, then, on mixing as before, and applying the lighted taper, the mixture burns rapidly, with a rushing or roaring noise, indicating what would happen on a large scale, supposing the fire-damp and air were mixed in a similar manner.

Fig. 60. A. Passing coal gas into a narrow-mouthed bottle in the pneumatic trough. B. Bottle half full of coal gas, and the remaining half water; the latter is falling out, and the air is taking its place.

Sir H. Davy found the fire-damp much less combustible than other inflammable gases. It was not exploded or fired by red-hot charcoal or red-hot iron: it required iron to be white-hot and itself in brilliant combustion for its inflammation. The heat produced by it in combustion was likewise much less than that of most other inflammable gases, and hence, in its explosion, there was much less comparative expansion. On mixing one part of carbonic acid, or fixed air, with seven parts of an explosive mixture of fire-damp, or one part of azote, or nitrogen, with six parts, their powers of exploding were destroyed. In exploding a mixture in a glass tube of one-fourth of an inch in diameter and a foot long, more than a second was required before the flame reached from

one end to the other; and Davy found that in tubes of one-seventh of an inch in diameter, explosive mixtures could not be fired when they were opened in the atmosphere; and that metallic tubes prevented explosion better than glass tubes. Sir H. Davy then had a lamp constructed with narrow tubes above and below, and he says: "In trying my first tube-lamp in an explosive mixture, I found that it was safe; but unless the tubes were very short and numerous, the flame could not be well supported; and in trying tubes of the diameter of one-seventh or one-eighth of an inch, I determined that they were safe only to small quantities of explosive mixture, and when of a given length; and that tubes even of a much smaller diameter communicated explosion from a close vessel. Hence I took a new method of ascertaining the safety of my apertures and of trying different forms of apertures. I had a vessel furnished with wires by which the electrical spark could be taken in an explosive mixture, and which was larger in capacity than a safe lamp or lantern was required to be. I placed my flame sieves—*i.e.*, my systems of apertures—between this jar and a bladder containing, likewise, an explosive mixture, and I judged the apertures to be safe only when they stopped explosion acting upon them in this concentrated way." Sir H. Davy at last arrived at the conclusion that a *metallic tissue*, however thin and fine, of which the apertures filled more space than the cooling surface, so as to be permeable to air and light, offered a perfect barrier to explosion, from the flame being divided between, and the heat communicated to, an immense number of cooling surfaces; and he at length arrived at one evidently the most simple—viz., *that of surrounding the light entirely by wire gauze, and making the same tissue feed the flame with air and emit light.* We can imagine Sir H. Davy's satisfaction when, as he says: "In plunging a light surrounded by a cylinder of fine wire gauze into an explosive mixture, I saw the whole cylinder become quietly and gradually filled with flame. The upper part of it soon appeared red-hot, yet *no* explosion was produced."

Fig. 61. The first Safe Lamp.

The first safety-lamp was constructed of fine wire gauze shaped in the form of a cylinder and about ten inches long, two inches in diameter, and closed at one end with wire gauze. Soft clay was then moulded and pressed around the middle of a lighted candle, and this was covered with the wire-gauze cylinder, so that the lower edge of the gauze was firmly pressed and embedded in the lump of clay. If such a lamp is held before a pipe from which coal gas is escaping, the latter burns *inside* the cylinder of wire gauze, but does not communicate with the exterior gas. In Sir H. Davy's later experiments, he employed coal gas because it takes fire at a lower temperature than fire-damp; and therefore, if his lamps stood the higher test of coal-gas mixtures, they were sure to answer in fire-damp mixtures. Indeed, he says, "I placed my lighted lamps

in a large glass receiver through which there was a current of atmospherical air, and by means of a gasometer filled with coal gas, I made the current of air which passed into the lamp more or less explosive, and caused it to change rapidly or slowly at pleasure, so as to produce all possible varieties of inflammable and explosive mixtures; and I found that iron wire gauze, composed of wires from one-fortieth to one-sixtieth of an inch in diameter, and containing twenty-eight wires or seven hundred and eighty-four apertures to the inch, was safe under all circumstances in atmospheres of this kind; and I consequently adopted this material in guarding lamps for the coal mines, when in Jan. 1816, they were immediately adopted and have long been in general use."

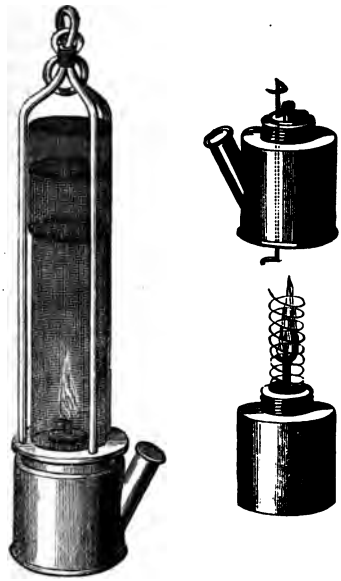


Fig. 62. Sir H. Davy's Lamp, as used in Coal Mines.

It deserves to be remarked, that when Sir H. Davy was pressed to secure his safety-lamp by patent rights, he rejected the idea of making money by his philosophical discoveries, saying, "I have enough for all my views and purposes; more wealth might be troublesome, and distract my attention from those pursuits in which I delight. More wealth would not increase my fame or my happiness."

Since Davy's time a great many improvements have been suggested in the construction of the safety-lamp, but none adopted, chiefly because the "butty" system is opposed to any change of candles or lamps that involves an outlay of money. "The butty men" have always made an enormous per-centage out of the miners; and whenever any good novelty, such as Simons' patent safety-lamp, is proposed, they play upon the weakness of the poor ignorant men, and encourage them to oppose everything likely to be introduced into the mine that will interfere with their profits. The order of succession in which a great number of mines are worked is as follows:—First, the *owner*, who lets the mine to second persons called the *contractors*. These gentlemen never enter the mine, and know nothing about the management or the miners. The contractor makes the best bargain he can with the third person, the *butty*, who is usually a man only one grade above the ordinary pitmen; frequently a man from their own rank. He perfectly understands the

prejudices and weaknesses of the poor fellows who spend nearly half their lives in the coal pit and the other in bed, and so manages that a very small sum out of every twenty shillings' worth of labour shall reach them in the shape of current coin of the realm.

The principal danger arises from the men removing the wire gauze from their lamps, and, in order to prevent this folly, Mr. Simons has invented a self-extinguishing lamp, in which an extinguisher falls over the light directly a man attempts to unscrew the wire gauze. This lamp has already been described and illustrated in the "Boy's Playbook of Science," and therefore need not be repeated here; it is, in fact, the original "safety-lamp" of Sir Humphry Davy, with Simons' self-acting extinguisher.

In the next cut the different forms of lamps and candles (all provided with spikes to fix into the walls of the galleries in which the men work) are fully depicted and explained, being those supplied for the purpose by Mr. Simons, of 84, Dale-end, Birmingham.

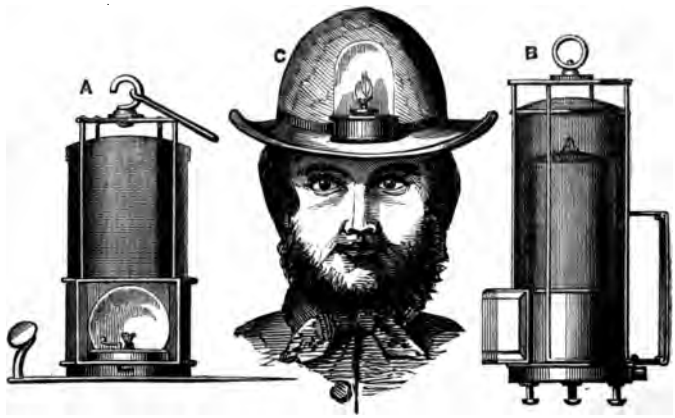


Fig. 63. A. Miners' Safety Lamp for fixing or hanging in any part of the mine where danger from any sudden or unexpected appearance of gas is to be apprehended, but where the work is progressing, and a good, steady, and safe light is required. This lamp will give the light of six candles, which can be directed to any desired point. It is under lock and key; a piece of talc is suspended from the top of the gauze to prevent the flame from burning through it, and also in front of the glass to protect it from the heat. The lamp will burn from six to eight hours without any interference after being trimmed and put into the miner's hands for use.

B. A Miner's Perfect Safety Lamp with all the different advantages of the above; but, in addition, a ring at the top, prevented from getting heated by a non-conductor, and also a handle to the side, so that it can either be carried about or hung up as may be needed. This is under lock and key, and will have a self-acting extinguisher, so that the lamp cannot possibly be opened without extinguishing the light.

C. A Cornish Miner's Skull-cap Lamp, for carrying on the head, or on the front of the wheelbarrow, when going up the adit, and reversing when returning. It is easily removed to fix wherever it is required.

The consideration of the Davy lamp naturally involves a few remarks upon the accidents with fire-damp which it is intended to prevent; and, perhaps, one of the most fearful on record is that which took place at the Lundhill colliery on the 19th of February, 1857, when about *one hundred and eighty* men and boys lost their lives. The pit is in the neighbourhood of Barnsley, and near the Wombwell station of the South Yorkshire Railway, and the accident is thus graphically described by the author of "An Hour in a Coal Mine," in "Chambers' Journal":—

"The men work in three gangs eight hours each, and, of the two hundred who formed the gang which commenced work at six o'clock in

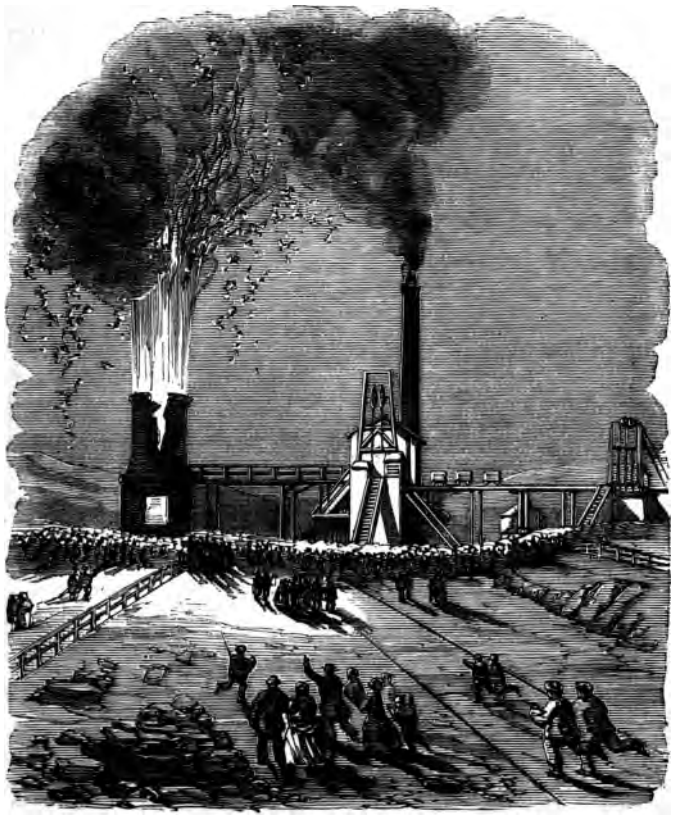


Fig. 64. The Ventilating Shaft on Fire at the Lundhill Colliery.

the morning of the day in question, not one-fourth came out of the pit alive. About noon, those above ground felt the earth tremble, and heard a smothered sound, which told only too certainly of disaster. Wives left their simple preparations for dinner, children their play, and all hastened to the pit's mouth. There they soon learned that an explosion of such extreme violence had taken place in the mine as to tear away the drawing ropes and destroy the apparatus for ascending and descending the shaft. About two o'clock volumes of smoke issued from the chimney of the ventilating shaft, and an hour later a magnificent, but terrible, body of flame shot up therefrom, indicating the ignition of inflammable gases below, and giving heart-sickness to all the lookers-on, who thought the while of husbands and fathers, sons and brothers, down in the fiery bowels of the earth. It was a fearful crisis. The mine was evidently on fire, and no one could go down to aid the sufferers. The managers felt the full extent of their responsibility. If they closed up all the shafts and pit's mouths, it might seem like consigning the poor miners to certain destruction, and yet if they did *not* do so, there was danger of the fire spreading and burning with such intensity as to cause the fall of the bed of coal and superincumbent earth, the consequent falling in of the shafts, and the inextricable loss of the bodies of those below. They hastily called a meeting of colliery owners and other persons in the neighbourhood, and it was not until fortified by the approval of *all* that the managers decided on closing the shafts, and thus smothering the fire. Before doing so, however, several venturous men descended one of the shafts, rescued nineteen miners who had saved their lives by clustering just at that spot, and then made two hours of exploration under circumstances as frightful as men could well be exposed to; dead bodies, dense volumes of sulphurous smoke, and fiercely blazing masses of coal were what they came upon in all the avenues and passages. When the dead and the living, so far as they could be found, had been drawn up, the shafts were closed and the mine flooded with water to quench the flames. It was a mournful scene when, after the water had been again drawn off, the charred and soddened corpses were drawn up one by one for Christian burial. Since the accident no naked candles are allowed in the pit, and no blasting with gunpowder, and the Lundhill colliery is again at work with its hundreds of fearless miners."

We may turn from these scenes of misery to one of those rare pictures which is presented annually in the coal-mine districts belonging to that most noble lady the Marchioness of Londonderry, who once a year entertains her workmen and miners to the number of three thousand souls.

It is unnecessary to detail the quantities of good cheer consumed on these occasions, or to report the speeches with which the banquet terminates. The address *par excellence* is that of her ladyship, who shows the benevolent interest she takes in those who contribute to her wealth by the sound practical advice and affectionate admonition and warning that she gives them, always entreating her miners to be careful

and not to imperil their own or fellow-labourers' lives by removing the wire gauze from their lamps to light their pipes or "fire their shots;"

Fig. 65. The Marchioness of Londonderry's Banquet to the Workmen and Miners engaged in her Coal Fields.

but to remember their wives and families, the relations who depend upon them for their daily bread. Her ladyship is not content only with mere words, but by her numerous charitable acts shows that she is worthy of the high station in which it has pleased God to place her.

Although much has been said about the working of the coal pits in these pages, there are many practical facts which the limits of this book oblige us to leave unnoticed; and having traced the coal to the pit's mouth, the last points to be considered are the delivery, consumption, and durability of the supply of the coal, not only to our vast cities and manufactories, but to other countries, and especially France.

No one should leave the coal district of Newcastle without paying a night visit to the banks of the river Tyne, which is one of the high-roads for the transport of enormous quantities of the "black fruit of industry."

The scene is very imposing, the gigantic iron furnaces continually sending out great flashes of fire, which light up the country as if

Fig. 66. A Scene on the Tyne.

with a general conflagration; the trucks full of coal continually running down to the "staith machinery," by which the fuel is lowered into the coal-brigs, the cressets burning, the men shouting, the constant creaking of ropes and tackle, all indicate the bustle and work with which the coal is shipped for home and foreign ports.

The construction and working of the staith machinery is thus described by the author of "The Pits and Pitmen:" "From every pit a tramway runs connecting the mine with a railway, or with one of the thousand staiths which form so prominent a feature on the Tyne and Wear. These staiths are high wooden jetties running far enough into the river to allow ships to float at their extremities, even at low water. The tramway runs from the pit to the end of the staith, the latter usually forming an incline along which the loaded trucks, as they descend, pull up the empty ones. The ship to be freighted lies at the end of the staith; arrived there, the full truck is run upon a species of nicely-balanced framework calculated to swing down with the weight from the end of the staith, describing a fourth part of a circle, and coming to a

rest just over the open hatchway beneath. The breaksman or rider accompanies the truck in its descent, and, removing a bolt, he causes the bottom to give way in trap-door fashion, and the load of course sinks into the hold; while the well-balanced framework, immediately

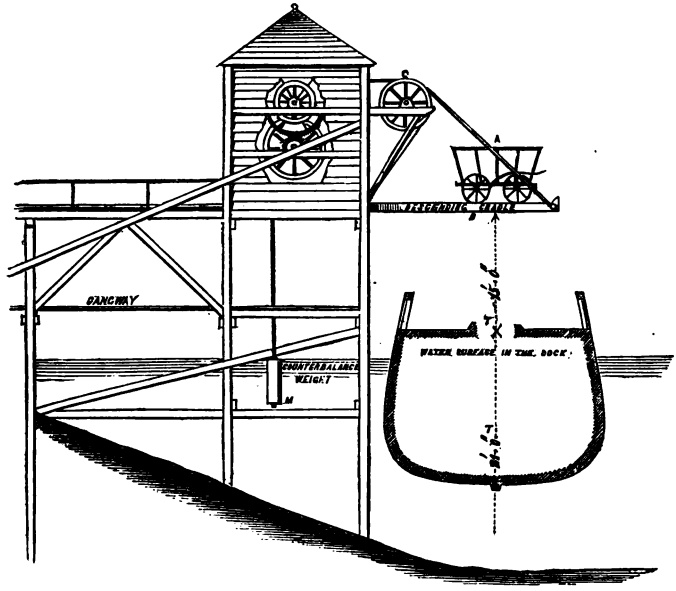


Fig. 67. One of the Forms of Staith Machinery.

rising as the weight is taken from it, swings up again to its former position, and the empty waggon runs up the incline as the next loaded one comes down. By this system the largest class of collier lading at a staith will have her cargo aboard in a tide. In the hold a gang of '*trimmers*' are at work distributing the coals, as the crews of the coal vessels never meddle with the cargo, either to stow it away, or in London to heave it out. The dingy fleet of colliers is calculated to be able to furnish at least 20,000 seamen to the British navy, in case a maritime war unhappily broke out."

Seeing the constant annual drain of sixteen million tons of coal from the northern pits, the question is naturally suggested, How long can this state of things last, and what is the period that calculation assigns for the duration of the supply?

We are assured by Professor Hunt, the keeper of the Mining Records

of the Government School of Geology and Mines, that the total annual produce of our three thousand British coal mines is not less than

"SIXTY-EIGHT MILLIONS OF TONS!!"

"It is very difficult [says a writer in the 'Edinburgh Review'] to convey an adequate conception of this vast produce; but if, as a collier has calculated, these sixty-eight millions of tons were excavated from a pit gallery six feet high and twelve feet wide, such a gallery must be 5128 miles and 1090 yards in length. Or if, instead of this tunnel of more than five thousand miles, we prefer the conception of a solid globe, then the diameter of a globe containing this annual produce must be 1549$\frac{9}{10}$ feet. Should a pyramidal form be chosen, then this quantity would constitute a pyramid the square base of which would extend forty acres, and the height of which would be more than 3356 feet. The great Egyptian pyramid of Ghizeh covers an area of more than thirteen acres, and rises a hundred and nineteen feet higher than St. Paul's, and twenty years were occupied in its erection. In England one year suffices, with the industry of 200,000 persons, to dig out coal that would build several pyramids as large as that of Ghizeh."

Professor Rogers, the State geologist of the Government of the United States of America, gives the following

"*Summary View of American and European Coal Fields.*

"The aggregate space underlaid by the vast coal fields of North America amounts to nearly 200,000 square miles, or to more than twenty times the area, including all the known coal deposits of Europe, or indeed of the whole Eastern continent. Comparing the assumed areas and solid contents of the coal fields of other countries with those of North America, we have the following results:—

"I. *Estimated Areas of Coal in Principal Countries.*

			Total sq. miles.
"United States . . .	196,650	sq. miles of coal area	200,000
British Provinces of N. America	7,530	"	
Great Britain	5,400	"	8,964
France	984	"	
Belgium	510	"	
Rhenish Prussian Saarbrücker coal field .	960	"	
Westphalia	380	"	
Bohemia	400	"	
Saxony	30	"	
Spain	200	"	
Russia	100	"	

"II. *Estimated Quantities of Coal in Principal Countries.*

	Tons.
"Belgium (average thickness, 60 feet of coal) .	36,000,000,000
France (about the same thickness)	59,000,000,000
British Islands (average thickness 35 feet) . .	190,000,000,000
Pennsylvania (average thickness 25 feet) . .	316,400,000,000
Great Appalachian coal field (same thickness)	1,387,500,000,000
Indiana, Illinois, Western Kentucky (25 feet)	1,227,500,000,000
Missouri and Arkansas basin (10 feet in thickness)	739,000,000,000
All the productive coal fields of North America, assuming thickness of 20 feet of coal over 200,000 square miles	4,000,000,000,000

"III. *The Ratio of the Estimated Quantities of Coal* in the more important of these several coal countries is shown approximatively in the following series of numbers, making the coal of Belgium, or 36,000,000,000 (thirty-six thousand million) tons, a unit of measure:—

"Amount of coal in	Belgium		1
,, ,,	France, less than		2
,, ,,	British Islands, rather more than . . .		5
,, ,,	Pennsylvania, a little less than . . .		9
,, ,,	Appalachian coal fields, about		38½
,, ,,	Missouri and Arkansas basin		20½
,, ,,	entire coal fields of North America . .		111
,, ,,	,, ,,	all Europe . . .	8¾"

In 1801 Mr. Bailey predicted the supply of the Durham and Northumberland coal fields would only last 200 years; in 1830 Dr. Buckland granted a larger period of 400 years; in the same year Professor Thomson extended the time to 1000 years; and Mr. Hugh Taylor exceeded all previous calculations by granting 1727 years. Mr. Hall, more recently, by careful calculation, estimated the time to be 331 years; which coincides precisely with the estimate of Mr. Greenwell, made in 1846; so that it seems to be understood the great coal fields of Northumberland and Durham will be hopelessly impoverished in about *three hundred years.*

In consequence of the immense consumption of coal in the iron furnaces and foundries of Staffordshire, it has been estimated that this coal field will be exhausted some time before the Northern fields, for the area of the former is scarcely more than one-half of the area of the latter; and even Yorkshire, Lancashire, and Derbyshire are more than living up to their income of coals. The quantity for supply being *fixed*, and the quantity demanded being continually on the increase, the actual period of exhaustion is not difficult to predict, though it may be unwelcome to anticipate. We shall, however, have resources at that period which will prevent a bituminous bankruptcy; and these will be found

in one or more coal fields not at present so largely worked as those previously named; particularly the great coal fields of South Wales will afford an abundant supply for many years to come. The whole question of the durability of the supply of coal is brought up to the present time in the following admirable review of the question by Professor D. T. Ansted:—

"As the extent of England's coal resources is an object of considerable interest at the present moment, perhaps the following statement of facts and inferences may be useful to remove unnecessary alarm, to suggest prudence in the management of so important an element of our country's greatness, and at the same time to justify our public men in permitting our neighbours to take a fair share of our mineral riches in return for those productions which the climate of the Continent and the ingenuity and industry of its people enable them to offer us in exchange.

"There are in England nine distinct tracts of country where those rocks come to the surface which are known to yield coal. These districts are called coal fields; the smallest of them includes more than 60,000, and the largest more than 600,000 acres of coal lands, under the greater part of which coal has been, is, or may be, worked to profit. Scotland contains another million of acres of such coal lands.

"Besides these tracts, marked in our geological maps, there are others exceedingly large, but less clearly made out, in which coal is also to be got, although the coal-bearing beds are covered up with accumulations of newer rocks. All these will be available when the price of coal justifies the outlay that will be involved in mining them.

"The best known and largest of our coal fields are the Newcastle and Durham, the Lancashire, the Yorkshire, the South Staffordshire and Warwickshire, and the South Welsh. The ascertained acreage of coal in these amounts to about 2½ millions. Adding to this the million of acres in Scotland, and half a million for the smaller areas, we have a total of four millions of acres, or, in round numbers, 6000 square miles of coal lands in the British islands.

"In none of these districts are there less than ten, while in some there are more than seventy beds of coal known and described, each capable of yielding coal to profit by the ordinary processes of mining. Some of these beds are between one and two feet, most of them between three and seven, and one between thirty and forty feet thick. Rarely more than a small number of seams or beds of coal can be obtained with advantage from the same area, but the average thickness of workable coal may with safety be taken as not less than fifteen feet, or five yards, over the whole area of any coal field.

"Now, as an acre contains 4840 square yards, and a cubic yard of solid coal weighs nearly one ton, there thus appears to be 24,200 tons of coal per acre of coal lands on a general average; but as a large quantity of coal in every coal field is, from various causes, not obtainable, and another large part is lost by the ordinary mode of extraction, we cannot calculate on more than one-third of this, say 8000 tons per

acre, as the quantity that can be removed and sold. This would give about 5,000,000 tons of coal for every square mile of coal lands.

"The annual consumption of coal at present in England cannot be less than 80,000,000 tons, so that we are now exhausting about sixteen square miles of our coal lands each year. Estimating the area of coal lands at 6000 square miles, this would give a duration of rather more than 350 years.

"It may be observed that the usual estimate of coal lands in England is 12,000 square miles, and that in the smaller area I have taken, an allowance is made for the unproductive portions.

"The coal area in Belgium and Rhenish Prussia together is not more than one-eighth part, and in all France not one-fifth part that of England and Scotland; the average thickness of coal is smaller, and the position of those coals is generally less favourable in the former district for extraction, and in the latter for transport to the sea.

"The quantity of coal known to exist in North America, both in the United States and British possessions, is so large, that for all practicable purposes it may be regarded as inexhaustible. Coal is also abundant in India, China, Borneo, Eastern Australia, and South Africa.

"Owing to the advanced position of England in practical mining operations, and the facility and economy with which she can place her large supplies in the markets of the world, at a cost so low at present as to exclude competition, her coal will no doubt be extracted very rapidly for years to come. But should the advancing industry of other countries reduce the price below that at which profit is secured by our colliers, or should the cost of extraction increase with us out of proportion to the rest of the world, the demand for exportation would be at once checked, and the drain upon our resources would diminish.

"That this must happen very long before any approach to exhaustion could be experienced, may be regarded as certain, and it must be remembered that the price of iron (for the manufacture of which at least half our coal is required) will to a large extent act as a regulator, and prevent a too rapid extraction when the first symptoms of exhaustion are felt.

"It is clear, then, that, like all other articles of commerce, the trade in coal may safely be left to arrange itself, and will do so with greatest certainty of benefit to all parties, both now and centuries hence, by being left to its natural growth, restrained only by those checks which nature has imposed."

We may now suppose that the collier brig has arrived in the vast port of London, and that her cargo is to be offered for sale at the market, viz., at the Coal Exchange, which is an ornamental building, where one of the most stupendous trades in the world is carried on. Mr. Timbs, in his most learned and entertaining work, "The Curiosities of London," informs us that the Coal Exchange, up to 1807, was in the hands of private individuals; in that year it was purchased by the "Corporation" for 25,600*l.* In 1845 the coal trade petitioned for the enlargement and rebuilding of the Exchange. This was done by the

City architect, J. B. Bunning; and the new Exchange was opened with great *éclat* by Prince Albert, accompanied by the Prince of Wales and

Fig. 68. The Coal Exchange.

the Princess Royal, October 29, 1849, when the Lord Mayor (Duke), himself a coal merchant, received a patent of baronetcy. The Exchange has two principal fronts, of Portland stone, in the Italian style, one in Lower Thames-street, and the other in St. Mary-at-Hill; with an entrance at the corner by a semicircular portico with Roman Doric columns and a tower 106 feet high, within which is the principal staircase. The public hall, or area for the merchants, is a rotunda, sixty feet in diameter, covered by a glazed dome seventy-four feet from the floor. This circular hall has three tiers of projecting galleries running round it; the stancheons, galleries, ribs of dome, &c., are iron, of which about 300 tons are used. The floor of the rotunda is composed of 4000 pieces of inlaid woods, in the form of a mariner's compass, within a border of Greek fret. In the centre is the City shield, anchor, &c.; the dagger blade in the arms being a piece of a mulberry-tree planted by Peter the Great when he worked as a shipwright in Deptford dockyard. The entrance vestibule

is richly embellished with rows of fruit, arabesque foliage, terminal figures, &c. In the Rotunda, between the Raphaelesque scroll supports, are panels painted with impersonations of the coal-bearing rivers of England—the Thames, Mersey, Severn, Trent, Humber, Aire, Tyne, &c., and above them, within flower borders, are figures of Wisdom, Fortitude, Vigilance, Temperance, Perseverance, Watchfulness, Justice, and Faith. The arabesques in the first story are views of coal mines—Wallsend, Percy Pit-Main, Regent's Pit, &c. The second and third story panels are painted with miners at work; and the twenty-four ovals at the springing of the dome have, upon a turquoise-blue ground, figures of fossil plants found in coal formations. The minor ornamentation is flowers, shells, snakes, lizards, and other reptiles, and nautical subjects. The whole is a polychrome by Sang. The gallery fronts and other iron-work are cable pattern. The cost of the enlarged site, the building, and approaches was 91,167*l.* 11*s.* 8*d.* In the basement, on the east side of the exchange, are the remains of a Roman bath, in excellent preservation, discovered in excavating the foundations of the new building; and there is a convenient access to this interesting relic of Roman London.

When the cargo is sold it is quickly transferred into large barges called lighters, which contain five compartments, called "rooms," each capable of holding seven tons of coal. The coal is further heaped upon every available space, until the lighter is freighted with about forty-two tons; and when the barge is open from stem to stern, it may be loaded

Fig. 69. Coalheavers at work.

with fifty-five tons of coal. The work of unloading the coal brigs is performed by the "whippers."

The duty is commenced by clearing the deck and opening the hatchways, over which an iron wheel called a "gin" is rigged out, or a rope passed over the top of a spar called the "derrick," at about eighteen or twenty feet above the deck. A rope is passed over this wheel, and at one end is slung the basket, and to the other four ropes are attached, which are held by four men called coalwhippers. These men, as may be noticed by any person passing by steamer from London to Blackwall, ascend some steps or rails from the pull, and directly the signal is given they descend rapidly, with a concluding jump, which brings the basket with a jerk to the "measure," and when this is filled, a sort of blow is heard, and the contents discharged by a broad trough into the "lighter" below. The price of coals, as given in the London markets in the daily newspapers, is the price up to the time when the coals are "whipped" from the ship to the merchants' barges. It includes, 1st, the value of the coals at the pit's mouth; 2ndly, the expense of transit from the pit to the ship; 3rdly, the freight of the ship to London; 4thly, the Thames dues; and 5thly, the whipping. The emptied coal ships are ballasted to Newcastle with gravel or sand chiefly dredged up from Woolwich Reach.

In olden time, before a cargo of coals could be discharged from a collier, it was necessary to obtain the permission of the Lord Mayor, who, for a certain consideration, granted the required permission. This much-honoured magistrate and his worthy coadjutors the aldermen, with the common councilmen and livery, called the Corporation, were permitted to lay a tax upon the "black diamonds" that amounted to something like 50,000*l.* per annum. In 1830 the heaviest of the coal duties were abolished; and since that time the trade has assumed those gigantic proportions which have made it the marvel of the civilized world. The first licences to dig coals were granted to the burgesses of Newcastle by Henry III., and in 1281 a very good trade existed in that fuel. A proclamation in the reign of King Edward I. shows the introduction of coal as a substitute for wood, and a charter of Edward II. indicates that Derbyshire coal was used in London. In the same reign coals were first sent from Newcastle for the benefit of those trades which required fuel; and in 1316 a petition was made from Parliament to the king praying his Majesty to forbid all use of the new and pestilent fuel called "coals," which was acceded to, and a proclamation made, commanding all use of "coals" to cease and determine, and threatening all who burnt coals to be mulcted, and on a second offence to have their furnaces demolished. In the reign of Queen Elizabeth the burning of stone coal was again prohibited during the sitting of Parliament. At a subsequent period, about 1648, coals were once more placed under a ban; and, as if to annoy the brewers to the utmost legal extent, the use of "hops" was at the same time forbidden. In 1520 Newcastle coal was first imported into Paris; but, as everybody knows who has visited that city, wood has been preferred to the soot-producing

mineral fuel. The Treaty of 1860 may work a remarkable change in this respect, and Paris become the "black sister" city to London.

After the expenses of lighters and lightermen come those of wharfs, officers and wharfingers, coalheavers, carmen, horses, waggons, sacks; and, speaking of the latter, housekeepers should count their sacks *before* and not *after* delivery.

Fig. 70. Delivery of the Coals. Coalheaver about to shoot the Coals into the Cellar.

The principle of contrast has always been recognised as one of the most telling portions of an argument or scientific explanation, because it is directly appreciated and understood. Thus we might talk for ever of the bulk or weight of the coal contained in our mines, or of the quantities annually consumed, without arousing any special wonderment in the minds of our readers; but when we change the word coal for its equivalent of human labour, and follow Mr. Henry Darwin Rogers in his explanatory calculations, then our respect for coal as the equivalent or exchange for human labour increases. Thus we are told "that each acre of a coal seam, four feet in thickness, and yielding one yard net of pure coal, is equivalent to about five thousand tons, and possesses, therefore, a reserve of mechanical strength in its fuel equal to the *life labour* of more than 1600 men. If we estimate a lifetime of hard human work at twenty years, giving to each year 300 working-days, then we have for a man's total dynamic efforts 6000 days. In coal this is represented by *three tons;* so that a man may stand at his own door while an ordinary quantity of coals is being delivered, and say to himself: "There,

in that waggon, lies the *mineral representative of my whole working life's strength!*"

The railroads are now the greatest opponents of the water-borne coals, and much to the satisfaction of Londoners. This great necessary of life is no longer controlled by wind and weather, but is supplied in never-ending successions of coal trains direct from the North to the streets of London. A retired coal merchant informed the author that, in the days of the supply by coal brigs, he once refused seven guineas a ton for the best "Wallsends," and that four guineas per ton was a common price formerly, when the City dues were exacted in all their ancient rigour. The old collier brig is fast giving place to the clipper screw steamer, which moves at least three times faster than the former, and again places the sea-borne coals on a level with those conveyed [per locomotive.

May our readers ever enjoy the delights of a happy fireside.

Fig. 71. "The last Scene of all"—Ashes.

Fig. 72. Alchemist in his Laboratory.

CHAPTER II.

THE ART OF ALCHEMY THE PREFACE TO THE SCIENCES OF CHEMISTRY AND METALLURGY.

THERE is probably no branch of chemistry which is so intimately connected with the alchemists as that important and very extensive section that refers to the metals and metallurgy; for this reason it would

hardly be doing justice to the subject if we omitted to say something about the doings of these ancient pioneers of chemical science, who, as Lord Bacon says, in their vain search for the philosopher's stone or the elixir of life, were like the young men of the fable who carefully digged and re-digged their father's field in search of a treasure which they never found, but whose labour was amply repaid by the fertility of the soil which they turned up with other intentions.

One of the greatest authorities on the literature of the subject is Dufresnoy, who commences his celebrated history of "Hermetic Philosophy" by telling his readers "that he is about to favour them with the history of the greatest folly and the greatest wisdom of which man can be capable;" and he very properly asks whether there is anything more insane than the wish to change the inherent nature of created things and to take to oneself, as it were, the supreme power of the Great Creator, or anything wiser than the desire to be prosperous and possess health and riches, to have the power to help friends and to solace the miseries of the poor? "Such are the men of whom," adds Dufresnoy, "I pretend to speak, and amongst whom are to be found plenty of foolish but very few wise men."

Dufresnoy then disclaims the idea of tracing back alchemy, or the art of transmutation, to the time of Tubal Cain, who is supposed by some authors to be identical with the Vulcan of mythological history; he will not accept the wild and mad-brained theory of the art being originally taught as the *pretium amoris* to mankind by the bad angels; in fine, Dufresnoy considers it is taking the history too far back to place it in the 1656 years that preceded the Deluge, and remarks, that it is sufficient to commence it long after that general inundation of the universe. In this judgment we think our readers will entirely concur; and, without troubling themselves to inquire whether Noah did or did not possess the fabulous elixir of life, or whether one of his descendants, Cham, was the first king of Egypt, formerly called Chemia, from Cham, and that from his name arose the name of chemistry—without entering upon such learned discussions, the students of alchemical history are satisfied to begin with the name of "Hermes Trismegistus," whose name is celebrated amongst the ancient Egyptians as the inventor of the arts and sciences, and especially physic, and who is said to have lived in the year of the world 2076. And here it may be mentioned that there are two great Egyptians of the name of Hermes; thus Hermes the Elder is supposed to be the same with Mizraim, or Canaan, the grandson of Noah; and Hermes Phthoth, or Mercury, surnamed Trismegistus the Younger, is supposed to have been the son of Mizraim; and it is in this way that the hermetic art is traced to the descendants of Noah. It is right to observe (for the benefit of those profane persons who would laugh outright if the foundation of chemistry was ascribed to a descendant of Noah) that this notion is founded on the work of Diodorus Siculus, of Agyrium, in Sicily, a celebrated historian and contemporary of Julius Cæsar and Augustus, who wrote his works about the beginning of the Christian era, and awarded the honour of the dis-

covery of chemistry to the Egyptian Hermes. No less than 36,000 books are said to have been written under the name of Hermes; but this prolific and astonishing authorship, surpassing even that of Dumas, is explained by Jamblichus, who states that a custom prevailed of inscribing all books of science with the name of Hermes. As Moses was learned in all the learning of the Egyptians, to him is also ascribed a knowledge of hermetic chemistry, or philosophy, affectedly called the sacred and divine art. Bishop Wilson, however, in one of his "Chemical Essays," denies the scientific skill of Moses, and says, "We have no reason to conclude that Moses either used the process of Stahl, or any other chemical means, for effecting the purpose intended;" and by quoting the verse, Exod. xxxii. 20, the worthy divine at once brings the theorists to facts: "*He took the calf which they had made, and burnt it in the fire, and ground it to powder, and strewed it upon the water, and made the children of Israel to drink of it.*" There is not the least intimation given of the gold having been dissolved, chemically speaking, in water. After the form of the calf had been destroyed by melting in the fire, it was stamped and ground, or, as the Arabic and Syriac versions have it, filed into a fine dust, and thrown into the river of which the children of Israel used to drink. Part of the gold would remain, notwithstanding its greater specific gravity, suspended for a time on the surface of the river, as may be easily proved by placing some gold leaf into a tumbler of water; and if the same kind of agitation be imparted to it as would prevail in a river, the gold might be swallowed with the water in the manner described by the sacred historian. Had the Israelites taken the gold in a state of chemical solution, they must have imbibed a rank poison.

The next in honour as an ancient student of chemistry, is Democritus, a celebrated Greek philosopher, who lived about 460 B.C., and is stated to have been the founder of the "atomic theory." Democritus was quite an ancient Humboldt, and his knowledge, like that of the latter philosopher, appears to have been most extensive, and embraced not only the natural sciences—mathematics, mechanics, grammar, music, and philosophy—but various other useful arts. Democritus, like Baron Humboldt, travelled into many distant countries solely in pursuit of knowledge. When it is stated that Democritus was the founder of the atomic theory, it is not to be supposed that he knew anything of the generalizations of chemistry, discovered only by analysis, or of the true meaning of the term *equivalent*: all that he disputed about was the finite or infinite divisibility of matters; and he was unable to affirm the simple truth that 8 is the equivalent or combining quantity by weight of oxygen, that 1 is the equivalent or combining proportion by weight of hydrogen, and that the two united make the equivalent of water, 9; or, indeed, to state the equivalents, or combining proportions by weight, of any or all of the sixty-three elementary bodies. If the nature of an element had been understood from the time of Democritus, we should have heard little or nothing of alchemy, for common-sense would as soon have thought of converting an elephant into a black beetle as to change

lead into gold. There can be no doubt that the Egyptians, the Chinese, and the Hindoos have, from time immemorial, exercised the arts of agriculture, sculpture, the working of metals, glass-making, and pottery. Their acquaintance with textile materials and the art of dyeing was by no means insignificant, whilst the stone pictures on the tombs at Thebes and elsewhere tell us of the conviviality and good cheer of the ancient Egyptians, and of the wine they made and the beer they brewed; but these same monuments give no hint of a knowledge of chemistry. There were three great periods of Egyptian art—viz., the Archaic, the ancient or obsolete, marked by the erection of the pyramids; the Theban, or most renowned period; and the Ptolemaic, or third period, when Egyptian art declined; and it may be supposed that it was at this period the "sacred art," or the attempt by the Egyptian priests to change the base into the precious metals, commenced, and which it was death to reveal to the uninitiated. The experiments of the Egyptian priests were conducted secretly in their temples, and the punishment of the peach-tree, which M. Hœfer conjectures to have been nothing less than a dose of prussic acid prepared by distillation from the crushed stones or leaves of some member of that family of plants, was awarded to those weak votaries who betrayed the secrets of the so-called *holy* or *sacred* art.

Humboldt, in his notes to "Cosmos," says—"The name chemistry indicates literally 'Egyptian art'—the art of the black land; for Plutarch ("De Iride et Osir," cap. 33) knew that the Egyptians called their country *χημια*, from the black earth. The inscription on the Rosetta stone has Chmi. I find the word chemie, as applied to the decomposing art, first in the decrees of Diocletian against the old writings of the Egyptians which treat of the 'chemie' of gold and silver (*περι χημιος αργυρου και χρυσου*)." The gaps in alchemical history are very wide, and we are obliged to leap to the second century of the Christian era, when Dioscorides, of Anazarba in Cilicia, a Greek physician, appears upon the scene as a practical philosopher, and the inventor of the technical art of distillation. About the same period Alexander of Aphrodisias described the distillation of sea water, and also indicated the distillation of wine. The art of distillation would make men acquainted with liquids having stronger power of effecting solution than water, and hence the learned Humboldt remarks, "that chemistry first begins when men have learnt to employ mineral acids as powerful solvents."

The work on "Materia Medica" written by Dioscorides is still extant, and was for many years received as a standard production. Suidas, a Greek lexicographer, who is thought to have lived in the tenth century, states that Diocletian ordered all the books on chemistry to be burned, lest the Egyptians, learning from them the art of preparing gold and silver, should thence devise resources to oppose the Romans. The edict of Diocletian occurred in the third century, but did not stop the progress of the fascinating art of alchemy. Suidas also defines chemistry to be the art of making gold and silver, and boldly explains the mythical story of the Argonauts and the Golden Fleece as an expedition undertaken to obtain a book teaching the profitable art of gold-making,

which was supposed to have been written by Hermes, the Egyptian king already alluded to.

One cannot help regretting that the epochs of chemical discoveries are so widely separated; and now we come per force to the period of the Arabians and the labours of Geber, or rather Abou Moussah Djafar, al Sofi, who flourished about the end of the eighth century, and is stated to have made the important discoveries of nitric and sulphuric acids, aqua regia, alcohol, and the preparations of mercury and other metallic salts. The preparation of nitric acid and aqua regia by Prince Geber is more than 500 years anterior to Albertus Magnus and Raymond Lully, and almost 700 years anterior to the expert monk, Basilius Valentinus. "Nevertheless," adds Humboldt, "the discovery of these decomposing [dissolving] acids, which constitute an epoch in chemical knowledge, was long ascribed to the three last named Europeans."

Whilst speaking of the refinement and learning of the Arabians at the period Prince Geber lived, it must be remembered that about 150 years before his time, Amrou, the lieutenant of the Caliph Omar, A.D. 651, had set fire to the immense library of Alexandria (which had already suffered severely by fire when Julius Cæsar was besieged in Alexandria), and totally destroyed it; to the great grief, no doubt, of all learned persons at that period, but especially of the philosophers who succeeded Geber. They never ceased to affirm that most probably the secret of transmutation could have been procured from the ancient books on hermetic philosophy in the Alexandrian library; and having declared the art of transmutation already discovered, their efforts were to be regarded as attempts to revive the lost precious secret.

If Geber lived about the end of the eighth century, he must have flourished in the reign of that most celebrated of Arabian potentates, the Caliph Haroun al Raschid, whose name will live for ever in the delightful fictions of the "Arabian Nights' Entertainments." The latter monarch had removed the seat of royalty from Damascus to Bagdad; "and that city," says Dr. Crichton, in his "History of Arabia," "then became the resort of poets, philosophers, and mathematicians from every country and of every creed. Ambassadors and agents in Armenia, Syria, and Egypt were ordered to collect the most important books that could be discovered. Hundreds of camels might be seen entering Bagdad, loaded with volumes of Greek, Hebrew, and Persian literature; and such of them as were thought to be adapted to the purposes of instruction were, by the royal command, translated by the most skilful interpreters into the Arabic language, that all classes might read and understand them. Thus it happened that the great works of Aristotle were only known and translated from the Arabic in later periods.

Dioscorides, A.D. 200, describes the distillation of mercury from cinnabar by means of an *embic*, or rather ambix, a Greek word signifying a kind of cup, or cover of a pot, from which, by adding the Arabic *al*, signifying *the*, we have Alembic, or rather Al-ambic; whilst the word Alchemy, which appears to have been specially adopted about the time

of Geber, is likewise derived from the Arabic, and means—*al*, the, and *kema*, dark or secret; indeed, the reader will have little difficulty in recognising terms of Arabic derivation in the words, Al-kali—*al*, the, and *kali*, a marine plant, now called glasswort, or marsh samphire; also in Algebra, Alcoran, Alcove, Almanack, Alcahest, or universal solvent, and many others.

It is difficult to say what kind of vessels were employed by the Egyptians or their successors in hermetic philosophy; and it is not until we come to the period of Geber that we are enlightened as to the forms and peculiarities of chemical glasses, and the construction of furnaces. These were *aludels*, or adopters; curcubites, or retorts; alembics, or lymbeckes; matrasses, or bolt-heads; pellicans, or digesters. Some of the chemical vessels invented by Geber are still employed in certain metallurgical operations, and retain their original names; thus in Almaden, a famous mining district in Spain, in New Castille, where of course many traces of the Moors, the descendants of the ancient Arabians, would remain, they still employ the "aludel" furnace for the distillation of mercury from the ore.

Fig. 73. Mode of arranging the Aludels or Adopters, at Almaden, for the condensation of the mercurial vapour. At A A A the joints are closed with a clay lute.

These adopters, in twelve long rows of twenty-five each, are connected with a large circular chamber, in which the ore of mercury is placed, and after the heat has been applied for about twelve hours, the mercury is driven off, and by means of the aludels and other parts of the condensing arrangement, the mercury is obtained in the liquid state. It is said that the Almaden quicksilver mines have produced more than ten million pounds in one year.

Sir H. Davy very properly remarks that the "apparatus essential to the modern chemical philosopher is much less bulky and expensive than that used by the ancients. . . . . All the implements absolutely necessary may be carried in a small trunk; and some of the best and most refined researches of modern chemists (such as those of Dr. Wollaston) have been made by means of an apparatus which might with ease be contained in a small travelling-carriage, and the expense of which is only a few pounds. . . . . It was said by an author belonging to the last century of alchemy, that *its beginning was deceit, its progress labour, and its end beggary*. It may be said of modern chemistry, that its beginning is pleasure, its progress knowledge, and its objects truth and utility." There are no doubt great intellectual qualities necessary for discovery or for the advancement of science.

In Zweibrucken (two bridges), in Bavaria, large quantities of mercury are distilled from the ore, which is placed in a number of earthen curcubites, or ancient retorts. These are all arranged in one gallery, where

the heat is applied, and their mouths fitted into receivers containing a certain portion of water.

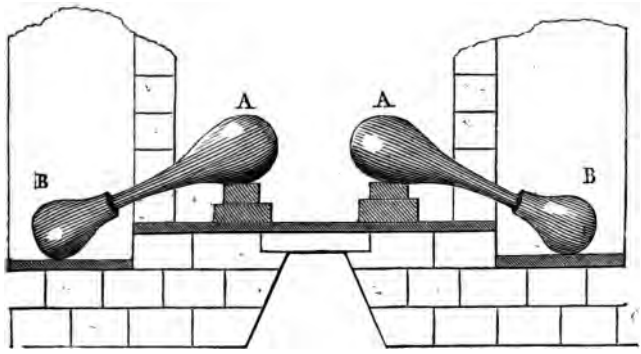


Fig. 74. A, A. Curcubites containing Mercurial Ore. B, B. The Receivers half full of Water.

That the alchemists used their curiously-twisted and distorted chemical vessels to some purpose is shown, not only in the chemical results of their labours, but likewise in the remarkable speculations they made with respect to future wonders in science and the mechanical arts. These anticipations became almost prophetic when clothed in the noble and enthusiastic language of such a man as the good old learned Friar Bacon, truly one of the "good old monks," and depositaries of that scanty amount of learning saved from utter oblivion in some of the monasteries and religious houses of Europe. Thus Bacon says:—

"Bridges unsupported by arches can be made to span the foaming current; man shall descend to the bottom of the ocean, safely breathing, and treading with firm step on the golden sands never brightened by the light of day. Call but the secret powers of Sol [heat] and Luna [cold] into action, and behold a single steersman sitting at the helm, guiding the vessel which divides the waves with greater rapidity than if she had been filled with a crew of mariners toiling at the oars. And the loaded chariot, no longer encumbered with the panting steeds, darts on its course with relentless force and rapidity. Let the pure and simple elements do their labours; bind the eternal elements and yoke them to the same plough."

Here we have suggested, in the middle of the thirteenth century, suspension-bridges, diving-bells, and submarine apparatus such as a modern Heinke would have improved upon. Coal fires and steam condensed by cold are suggested for propelling ships, whilst steam-carriages and locomotives relieve the panting steeds. Let the pure and simple elements—meaning earth, represented by fuel, air to feed the furnace, fire to boil the water, and water to generate the steam—do their

labours. How far Friar Bacon's recommendations have been attended to we perceive in the colossal Britannia tubular bridge and the mammoth Victoria bridge, which his Royal Highness the Prince of Wales has so lately opened with such *éclat* in Canada, and in the complete success of diving apparatus; likewise in the almost countless miles of road only used by steam horses—all honour to Friar Bacon!

The next cut, taken from a chemical book printed in 1662 (two years after the restoration of King Charles II.), with its quaint drawing and spelling, affords a good idea of the shape of the glass vessels employed for chemical experiments; and they are, no doubt, nearly all copies of those originally proposed by Geber.

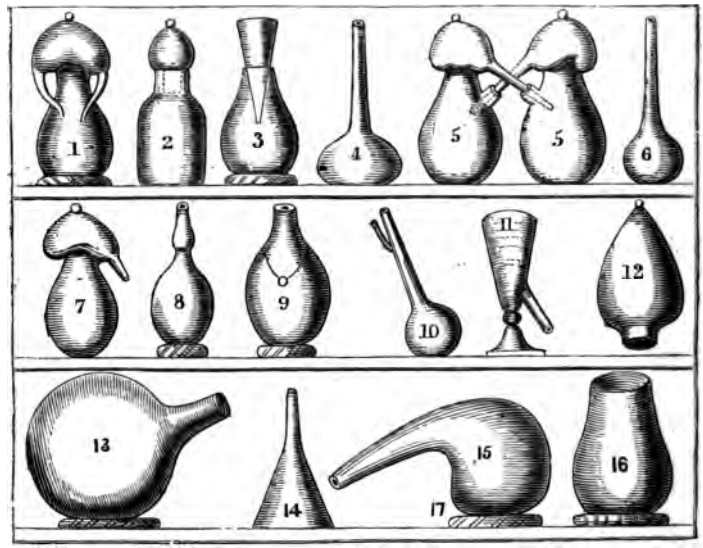


Fig. 75. 1. A Pellican, or circulating vessel. 2. Another vessel of circulation. 3. An infernall glass. 4. A Matrace, or boult head, with a flat bottom. 5, 5. A Troir, or double Pellican. 6. A Matrace, or boult head. 7. An Alimbick made of one peece, or a head and body joyned at the first making. 8. The Phylosopher's egg. 9. A double egg, or one within another. 10. A little Matrace. 11. A separating glass. 12. A blind head, or a head without a beak. 13. A receivour. 14. A glass funnell. 15. A Cornue, or a retort. 16. A Curcabit, or a body for an alimbick. 17. A ring, or round roule of straw, to hould glass vessels.

The heat-giving agents employed by the alchemists were both natural as well as artificial; thus, the rays of the sun were not forgotten, but were made use of, and reflected by a mirror on to the alembic, from which the distilled liquid passed. (Fig. 76.)

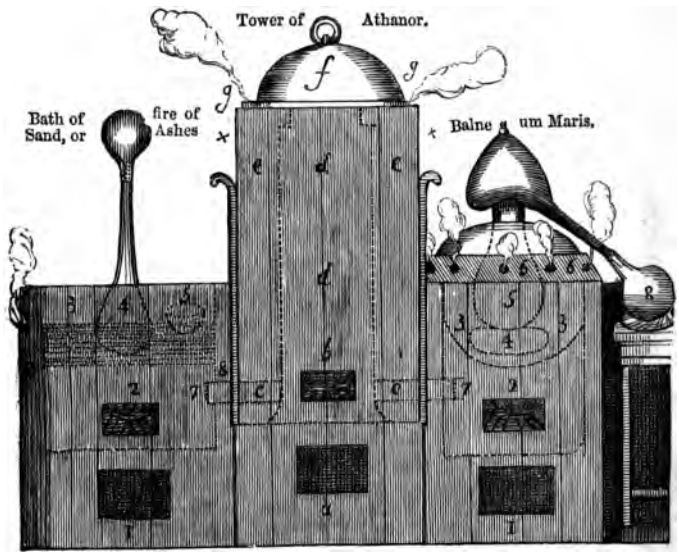
Fig. 76. Sun's Rays reflected on to an Alembic by a concave Mirror.

Or else the curcubites, or vessels with long necks, used sometimes for retorts, were placed directly in the sun's rays, and the operator was recommended to use this kind of heat only in the months of July and August.

Fig. 77. Alchemist placing Curcubites in the Sun. The Assistant is occupied grinding and mixing the Lute for closing the Curcubites.

One of the great achievements of Geber was the construction of his large furnace, or Tower of Athanor, which was provided with a somewhat lofty receptacle, called the Turret, for the fuel, and as the lower portion burnt away, the combustible matter continued to descend, so that it was like a modern furnace fitted with a hopper, and as long as the upper part, D, was kept full of coal or charcoal, it never went out, and was hence called the Athanor, or *undying one*.

It is to be noted in these Figures and the following There are some Geometrical, some Optical made with a weake shade, the better to discerne the internal parts, which are onely represented with punctuated lines.



[Fig. 78. The Tower of Athanor.]

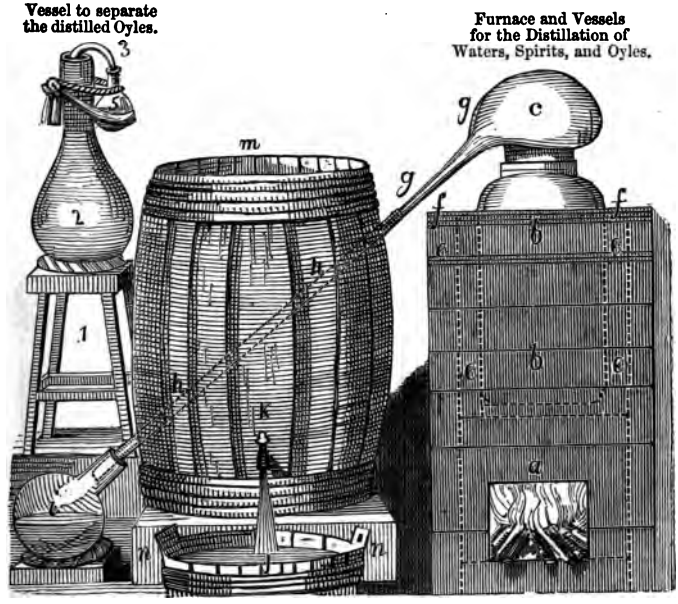
1. the ashe hole.
2. the focus or fire roome.
3. the place where the ashes or Sand for the Bath are placed.
4. a Matrasse.
5. a glasse dish.
6. the Register of fire.
7. the entrance of the fire or heat from the Tower of Athanor.
8. the Iron plate or Vessel containing the Sand or ashes.

a. the ashe hole.
b. the focus or fire roome.
c. the passages made for comunication of the fire.
d. the empty place of the Tower.
e. the solid part of the Tower.
f. the cover of the Tower.
g. two severall circles wherein the cover is inlayd.

1. the ashe hole.
2. the focus.
3. the kettle where the water of the Balneum is put in.
4. a round (of wood, hay, or some other soft matter) to keepe vp the Limbeck body.
5. the curcubite with its Limbeck head.
6. the Registers of fire.
7. the stoole or table to keepe up the Recipiem.
8. the Recipiem.

This arrangement is highly commended by Le Febure, 1662, for the following reasons: "Because this furnace is not only the most useful of all others to perform at the same time several operations, but also because it saves coals, easeth the care and assiduity of the artist, and yields a heat easily to be regulated. The Athanor is consisting of four parts. The first is the turret containing the coals; the second, or Balneum Maris [water bath]; the third, an ash; the fourth, a sand furnace."

The alchemists do not appear to have confined themselves only to the use of the sun's rays or the furnace, but employed the heat arising from



[Fig. 79. Alchemical Distillation.]

a. the fire.
b. the glasse body for distillation (vesica).
c. the Moores head.
d. the iron bar which keepes vp the glasse body.
f. the Registers of the fire.
g. the pipe or nose of the Moores head.
h. the pipe (sometimes worme) passing through the barell full of water.
i. Recipiem.
k. the cock to draw out the water when it must be changed.
l. a tub to receive the water let out.
m. the barrell or caske containing the water to coole and condense the spirits.
n. the prop or support of the barrel or cask.
1. a stoole or small table to keepe out the recipiem.
2. recipiem with the water to be separated.
3. Cotton drawing the oyle and swiming aboue the water.
4. Oyle swiming above the water.
5. a small glasse viall to receive the Oyle.

dung in a state of putrefaction or fermentation, and likewise lamp or candle heat. It is impossible to assert that Geber ever worked with any other heat than that of his Athanor, although to such a close observer of "common things" the constant burning lamp might have suggested its own application.

Dr. Johnson, the great lexicographer, asserts that the origin of the word *gibberish*, signifying that which is very outlandish and difficult to understand, arises from the name of Geber, because his works were written in such a very unintelligible style; but the great difficulty is to affirm what Geber really did write, because his name is made use of as the author of a great number of trumpery, nonsensical books on alchemy, with which he had really nothing whatever to do; in fact, the dishonest alchemists of later times merely adopted his name to sell their trash, which they neither understood or believed in themselves. Witness Salmon's "Geber," from which we will quote a few lines, and then compare them with some of the genuine writings of Prince Geber, which have been carefully collected by Hœfer.* Salmon makes him say, with a vast deal of other trash, referring to the Philosopher's Stone, "Hence we define *Our Stone* to be a generalizing or *Fruitful Spirit* and *Living Water*, which we name the *Dry Water*, by Natural proportion cleansed and United with such Union, that its principles can never be separated one from another; to which two must be added, a third for shortening the work, and that is one of the perfect Bodies attenuated or subtilized."

The reader can well imagine unhappy believers in transmutation wading through such muddy instructions, and after spending their time and money, having literally nothing for their trouble. No doubt poor Geber's name has often been sadly reviled by unsuccessful searchers after the stone; whereas, if they could have obtained his genuine works, they would have discovered that he denies the possibility of transmutation, and gives advice that might be printed and hung up in every laboratory. "The chemist," says Geber, "must be sound in mind and in body; he who suffers himself to be led away by his imagination, his vanity, or his vices, is as incapable of success as if he were blind or mutilated. The greatest patience and sagacity are required. When a difficult experiment has been commenced, which does not at first succeed, we must take courage to persevere, and follow it to the end, never stopping half way; for an imperfect and unfinished work, far from being useful, is hurtful to the progress of science." With respect to transmutation, he says, "It is as impossible to transmute the metals as it is to change an ox into a goat; for, if nature employs a thousand years to form the metals, how shall we pretend to do so whose lives are so brief? It is true that the heat we employ may produce sometimes, in a short period, that for which nature requires years, but how slight is the advantage in this respect!"

Geber was well acquainted with, and described, the properties of gold,

* "Histoire de la Chimie," par F. Hœfer.

silver, mercury, copper, tin, iron, lead, and arsenic. He was also acquainted with the processes of sublimation, distillation, calcination, solution, crystallization, and he fully explains the art of assaying gold and silver by the cupel; also the preparation of nitrate of silver, corrosive sublimate, red oxide of mercury, liver and milk of sulphur, the mineral acids, caustic potash, magnesia, sal-ammoniac, and phosphate of soda. Geber, like those who had preceded him, believed that the metals were of a compound nature, and consisted of mercury and sulphur, with occasionally a third element, arsenic, from whose varying proportions and modes of combination the difference among them resulted.

Geber's mercury, sulphur, and arsenic were not the real substances, having the ordinary characteristics of these metals, but were certain imaginary and theoretical principles supposed to exist, real elements of matter, and from which all the metals were supposed to originate. Geber's successors lost the meaning of the great chemist's elements, and thus degenerated into the fanciful notion of metals growing from seeds, just as if they were endowed with the living organism of plants.

It is from the Arabians we have the abbreviations of words by signs, which save their constant repetition, as in the well known signs of plus and minus; and no doubt from the same refined people originated the alchemical signs for the metals and other chemical substances. These signs are now only seen upon the show bottles of chemists' shops, and some of them probably will be recognised in the next cut.

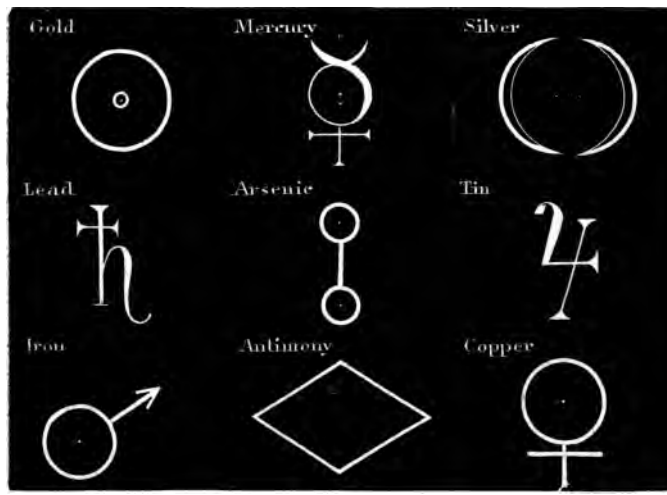


Fig. 80. Alchemical Signs of the common Metals.

Prince Geber appears to have been succeeded by several learned Arabians, amongst whom particular notice is made of Alfarabi, who was murdered by some thieves in the deserts of Syria, A.D. 954, and also of Avicenna, whose real name was Ebn Cinna. This alchemist was born at Bokhara, A.D. 980, and, in consequence of the great reputation he enjoyed as a physician and alchemist, was made Grand Vizier by the Sultan Magdal Dowleth. This elevation is stated to have led to his moral degradation and downfall, as he was dismissed from his office in disgrace and died prematurely, worn out by debauchery, A.D. 1036.

After the lapse of about 150 years from the period of the last-named alchemist, and 400 years from the time of Geber—viz., in the year 1193—the celebrated Albertus Magnus was born, who, with his pupil Thomas Aquinas, made great exertions to obtain the philosopher's stone and elixir vitæ. It was this clever man who constructed the "Brazen Head" which had the power of talking, and on one occasion it chattered so fast that Thomas Aquinas took up a hammer and broke it to pieces. The Brazen Head must have been some acoustic contrivance by which the voice was rendered audible, most probably through the medium of an ordinary speaking-pipe. It is Albertus Magnus who was said to have the power of changing the course of the seasons, and the story is thus related by Charles Mackay * from Lenglet's "Histoire de la Philosophie Hermetique." Albertus was desirous of obtaining a piece of ground, on which to build a monastery, in the neighbourhood of Cologne. The ground belonged to William, Count of Holland, and King of the Romans, who, for some reason or other, did not wish to part with it. Albertus is reported to have gained it by the following extraordinary method:—He invited the Prince, as he was passing through Cologne, to a magnificent entertainment prepared for him and all his court. The Prince accepted it, and repaired with a lordly retinue to the residence of the sage. It was in the midst of winter; the Rhine was frozen over, and the cold was so bitter that the knights could not sit on horseback without running the risk of losing their toes by the frost. Great, therefore, was their surprise, on arriving at Albert's house, to find that the repast was spread in his garden, in which the snow had drifted to the depth of several feet. The Count in high dudgeon remounted his steed; but Albert at last prevailed upon him to take his seat at the table. He had no sooner done so, than the dark clouds rolled away from the sky, a warm sun shone forth, the cold north wind veered suddenly round, and blew a mild breeze from the south; the snows melted away; the ice was unbound upon the streams, and the trees put forth their green leaves and their fruit; flowers sprang up beneath their feet, while larks, nightingales, blackbirds, cuckoos, thrushes, and every sweet song-bird sang hymns from every tree. The Earl and his attendants wondered greatly; but they ate their dinner, and in recompence for it Albert got his piece of ground to build a convent on. He had not, however, shown them all his power. Immediately that the repast was over, he

* "Memoirs of Extraordinary Popular Delusions," p. 16.

gave the word, and dark clouds obscured the sun; the snow fell in large flakes; the singing birds fell dead; the leaves dropped from the trees, and the winds blew so cold and howled so mournfully, that the guests wrapped themselves up in their thick cloaks, and retreated into the house to warm themselves at the blazing fire in Albert's kitchen. The sober reader would at first class this story with all other tales of wonderful necromancers and sorcerers, until he remembers that a tropical warmth and an abundance of growing plants, flowers, birds, is to be seen during the severest winters at the Crystal Palace and other places; and that most probably Albertus Magnus constructed the first winter garden, where he maintained an agreeable warmth, and charmed and astonished Wilhelm of Holland on the 6th of January, 1249, with this delightful novelty. As the company retired from the winter garden to finish the evening in Albert's kitchen, a great contrast would be apparent in the falling snow and the usual severities of winter; and if any of the birds had accidentally escaped from their glass-house at that moment, no doubt the intense cold might have caused their death, whilst probably, to show the King of the Romans that it was artificial heat which alone produced the results he had witnessed, some of the plants might have been placed outside, where their leaves would soon curl and betray the usual effects of Jack Frost. The first winter garden or hothouse, in the garden of the Dominican convent at Cologne, suggested this fable of Albertus Magnus. It would be an endless task to relate the histories of all the alchemists who lived in the period between the twelfth and seventeenth centuries; and therefore we shall only speak of the doings of the greatest celebrities, and content ourselves by merely naming the others.

Artephius, Alain de Lisle, Arnold de Villeneuve, Pietro d'Apone, Pope John XXII., Jean de Meung, Isaac and John of Holland, belong to the thirteenth and fourteenth centuries; likewise Raymond Lully and Roger Bacon, both of whom deserve notice here: the former because he appears to have been the first scientific Master of the Mint, being invited to England by King Edward, who assigned him apartments in the Tower of London, where he refined much gold and superintended the coinage of the "Nobles of the Rose;" and it is affirmed, made gold out of iron, quicksilver, lead, and pewter, to the amount of six millions. These statements, however, are denied by the writer in the "Biographie Universelle," who states that Raymond Lully never visited England, but his name has been mistaken for another Raymond, a Jew of Tarragona. Raymond Lully is worthy of praise, because he adopted Prince Geber for his model, and, instead of pursuing the pretended arts of astrology and necromancy, he studied most diligently the nature and properties of the metals. If this was the case, and he became intimately acquainted with the modes of refining gold and silver, no doubt Lully might have been of great service to King Edward, who is said to have detained him prisoner in the Tower, from which he ultimately escaped.

Both Raymond Lully and Roger Bacon were contemporaries of Albertus Magnus, and all three were extraordinary men of the age they

lived in. If the palm of superiority may be awarded to either, it would seem to belong to the famous Roger Bacon, or Bachon, as it is spelt in William Salmon's translations of the "Radix Mundi," and "Speculum Alchimiæ," alleged to have been written by the learned friar. He was born at Ilchester, in Somerset, in the year 1214, and, after studying at Oxford and Paris, Roger Bacon became a monk of the Franciscan order; and, had he contented himself with the performance of his chemical experiments and ordinary duties, no one would have interfered with the philosopher; but, taking upon himself to attack many of the dogmas of the Church, and to reform the abuses which had crept into the order of St. Francis, his brethren seem to have taken umbrage at these attacks and charges, and, seeking an opportunity to revenge themselves upon the reformer, he was very soon accused of witchcraft and sorcery, cast into prison, and nearly starved to death. He is said to have discovered many optical contrivances, such as the telescope, the use of concave and convex lenses, the magic lantern, and other effects of glass lenses; and,

Fig. 81. The House of Friar Bacon, at Oxford.

above all, he is named as the discoverer of gunpowder, a material which has wrought more wonderful changes in the great family of man than the most potent elixir that could have been devised to prolong life.

It seems very strange that a man like Roger Bacon, possessing such great and original powers of mind, should have been endowed with the somewhat grovelling notion of making gold; he might certainly have had the benefit of a doubt in this respect, if he had not left written statements of his belief in the possibility of transmutation. In one of his works called the "Mirror of Alchemy" he thus defines the art: "Wherefore, *Alchymie is the Art or Science teaching how to make or generate a certain kind of medicine which is called the* Elixir, *and which, being projected upon metals or imperfect bodies, by thoroughly tinging and fixing them, perfects them in the highest degree, even in the very moment of Projection.*" Again, in the 53rd chapter, where he speaks of the "Natural Principles and Generation of Metals and Minerals." III. "For, according to the Purity or Impurity of the said two, to wit, of *Argent Vive,** and Sulphur, pure and impure metals are generated, to wit, Gold, Silver, Tin, Lead, Copper, Iron; concerning the values of which—viz., of their purities and impurities, or superfluous corruption and defect, we have a few true things to say."

It is Geber's old idea of mercury, sulphur, and arsenic wrongly interpreted. With the single exception of his belief in transmutation, Roger Bacon stands out in all other respects as one of the most learned and original philosophers who have ever attempted to study nature's laws, and the great historian Hallam awards him very high rank, and even suggests, from the examination and comparison of Roger Bacon's "Opus Major" with the "Novum Organon" of Francis Lord Bacon, that the latter condescended to borrow a few notions from the worthy friar. We now pass to the fourteenth and fifteenth centuries, and the first name handed down by tradition as that of a successful alchemist is that of Nicholas Flammel, who was born at Pontoise about 1350, and having no property, he came to Paris to practise as a scribe, having received a fair education and being a good penman and well skilled in the learned languages. Although it appears he soon obtained employment as a scribe, the profit from his calling was so very small that he could hardly exist upon it, and, like a clever man, he began to turn his attention to more profitable work; selecting that which would excite the cupidity and awe of the ignorant, he commenced with alchemy, and astrology or fortune-telling. In these occupations he appears to have been very successful, and soon amassed sufficient money to take a house and marry his beloved Perrenelle. About this time Nicholas Flammel bought by chance a very curious old book for two florins, and it became ostensibly the means of procuring him an enormous fortune, with which, quoting his own words, as translated from the Latin by William Salmon, he says: "Before the time wherein I wrote this discourse, which was at the latter end of the year of our Lord 1413 (after the death of my faithful companion, whose

* Quicksilver.

loss I cannot but lament all the days of my life), she and I had already founded and endowed with revenues 14 Hospitals, 3 Chappels, and 7 Churches in the city of Paris, all which we had new built from the ground and enriched with Great Gifts and Revenues, with many Reparations in their Church yards."

The discourse alluded to refers to the remarkable book which concealed, under "Vails, Types, and Hieroglyphic Covertures," the wonderful art of Transmutation; and it is this work which Flammel is supposed to explain in Salmon's translation of his "Nicholai Flammel Hieroglyphica" as follows: "I, *Nicholas Flammel*, Scrivener, living in *Paris, anno* 1399, in the *Notary Street*, near *S. James* of the *Bouchery*, though I learned not much Latin, because of the poorness and meanness of my Parents, who, notwithstanding, were (by them that envie me most) accounted honest and good people . . . . After the decease of my Parents, I, *Nicholas Flammel*, got my living by the Art of writing, engrossing inventories, making up accounts, keeping of Books, and the like. In this course of living there fell by chance into my hands a Guilded Book very old and large, which cost me only the sum of two *Florens* [which was about 6*s*. 8*d*. formerly, now 10*s*. English]. It was not made of *Paper* or *Parchment*, as other Books be, but of admirable *Rindes* (as it seemed to me) of young trees. The Cover of it was of *Brass;* it was well bound, and graven all over with strange kind of Letters, which I take to be *Greek Characters*, or some such like. This I know that I could not read them, nor were they either *Latin* or *French* Letters or Words, of which I understand something. But as to the matter which was written within, it was engraven (as I suppose) with an *Iron Pencil* or *Graver* upon the said *Barke Leaves;* done admirably well, and in fair and neat *Latin Letters*, and curiously coloured. . . . . Upon the first of the Leaves was written in, Capital Letters of Gold, Abraham *the* Jew, *Prince, Priest, Levite, Astrologer, and Philosopher to the Nation of the Jews dispersed by the Wrath of God* in *France* wisheth health.

"After which words it was filled with many execrations and curses, with this word, MARANATHA (which was oft repeated), against any one that should look into it, to unfold it, except he were either *Priest* or *Scribe*." Here it may be observed that Flammel was sorely disconcerted when he comprehended the dire misery which was to fall upon the rash peruser of this precious volume, until he recollected that he was a scribe; when of course his scruples, with regard to the propriety of reading it, were satisfied and his fears vanished. He then goes on to say: "In the second leaf of the book he consolated his nation and gave them pious counsel . . . . to flee from *idolatry*, and to wait in patience for the coming of the Messiah. . . . . In the third leaf, as in all the writing that followed, he taught them in plain words the *transmutation* of metals, to the end that he might help and assist his dispersed people to pay their *tributes* to the *Roman* Emperors, and some other things not needful here to be repeated. . . . . The fourth and fifth *leaf* thereof was without any writing, but full of fair figures, bright and shining, or, as it were, enlightened, and very exquisitely depicted.

"But of the *Prima Materia*, or first matter or Agent, he spake not so much as one word; but only he told them that in the *fourth* and *fifth* Leaves he had entirely painted and decyphered it, and depicted or figured it with admiral Dexterity and Workmanship."

The next chapter of Flammel's book is devoted to the experience of his sadness and discontent in consequence of being unable to decipher or read the contents of the book; and after consulting all the wise and learned men of Paris, he tells us, "they understood thereof no more than myself. But the greatest part of them made a mock both of me and that most excellent Secret, except one whose name was *Anselme*, a practiser of Physick and a deep student in this Art." This profound thinker unfolds the *First Agent* to Flammel, by stating "that this without doubt was Argent Vive [quicksilver], which they could not fix, i.e., cut off his feet, or take away his volatility, *save by that long digestion in the pure blood of young infants*." A good and humane process, which Flammel tells us afterwards he accounted *Wicked* and *Villanous*, and never pursued, although he lost one-and-twenty years in a perfect *meander* from the *verity* by reason of the advice given by the deep student Anselme. "In the end, having lost all hope of ever understanding those *Symbols* or *Figures*, I made a Vow to God to demand their intepretation of some Jewish Priest belonging to some synagogue in *Spain*." Accordingly Flammel journeys to Spain, where he makes the acquaintance of a physician, one *M. Canches*, a *Jew* by nativity, but now a *Christian*, dwelling at *Leon* aforesaid. This worthy gentleman was completely ravished with the copies of the pictures of the book, which he appeared to have heard of and thought to be utterly lost, and, taking ship together, they both returned to France; where, as Flammel says, "he most truly interpretated unto me the greatest part of my Figures, in which, even to the points and pricks, he could decipher Great Mysteries which were admirable to me." Unhappily the good Canches dies suddenly at Orleans, where Flammel, always affecting poverty, says, "I hurried him (as well as my present condition would permit me)." He then returned to Paris to the great joy of Perrenelle; and having now the "Prima Materia," and devoting three years more to study, search, and labour, at length Flammel says: "I found that which I desired, which I also knew by the *scent* and *odor* thereof. Having this, I easily accomplished the Magistery. For, knowing the *proportions* of the *prime agents*, and then litterally following the directions in my book, I could not then miss the Work, if I would."

On the 17th January, 1382, about noon, being Monday, Perrenelle only being present, he made a projection upon a pound and a half of mercury, which he turned into *Pure Silver*, "better [says Flammel] than that of the mine, as I proved by assaying of it myself, and also causing others to assay it for me many times." "Again following exactly the directions in my Book literally and word by word, I made projection of the *Red Stone*, on the like quantity of *Mercury*, *Perrenelle* only being present, and in the same house; which was done in the same Year of Our Lord, *viz.*, 1382, *April* 25, at five in the afternoon. This Mercury I truly

transmuted into almost as much Gold, much better indeed than common Gold, more soft also and more pliable."

Flammel then raises a doubt about his wife's capability of retaining the secret, only the more to praise and commend her in the succeeding paragraph as a wise and discreet woman; and he remarks: "Above all she was exceedingly religious and devout; and, therefore, seeing herself without hope of children and now well stricken in years, she made it her business, as I did, to think of God, and to give ourselves to the work of Charity and Mercy;" and then Flammel gives that passage referring to the building of the hospitals, chapels, and churches already quoted at p. 132. Nicholas Flammel was celebrated for his Hieroglyphics which he caused to be placed in the churchyard of the Innocents, in the fourth arch entering by the great gate of Dennis Street, on the right hand. Alleged copies of these pictures adorn Salmon's translation of "Flammel," and will remind the reader of those precious works

Nicholas Flammel, Perrenelle his Wife.
lib. 3. ch. 27. sect. 9. 10.
chap. 30. sect. 1. &c.
lib. 3. ch. 27. sect. 11. 12
lib. 3. ch. 27. sect. 13. 15
chap. 31. sect. &c
lib. 3. ch. 27 sect. 11.
ch. 23. sect. I.

Fig. 82. Illustrations of Nicholas Flammel's Hieroglyphics, which admit, according to Salmon, of theological and philosophical interpretations. Chapter 27 in Salmon's work refers to the theological interpretation; Chapters 30, 31, and 32, to the philosophical.

of art to be discovered in Moore's *Almanac* and other edifying books of Fate, &c.

There can be no doubt that Nicholas Flammel practised alchemy, and died very rich; but those of his contemporaries who took the trouble to look carefully into the source of his wealth, affirm that he did not *make* his money literally by transmutation, but was a miser and usurer, and received, in the first place, great profits from his Jewish brethren when he visited Spain, apparently to obtain an interpretation of the book, but really to collect debts and settle accounts between the Jews living in France and Spain. Had it been known that Flammel was a collector of money, he might probably never have lived to return to France, but would most likely have been murdered for the sake of the property he carried about him. With the excuse of his well-planned story and apparent poverty he carried about his person documents, and, no doubt, jewels of great value, which, in the then unsafe condition of the public high roads, could not otherwise have been transported from one country to the other. After Flammel came George Ripley, Basil Valentine, Bernard de Treves, the Abbot Trithemius, the Marechal de Rays. This miserable wretch is supposed to have murdered at least one hundred children, of both sexes, at his castle of Champtocé, in those horrible mysteries which he believed would give him the philosopher's stone. He was finally arrested, and condemned to be burnt alive; the sentence, however, was modified in consequence of his high rank, and he was first strangled, then thrown into the fire, and his half-burnt body handed over to his relatives for sepulture. This nobleman, no doubt, was insane, and in modern times would have become the inmate of a *maison de santé*. In the year 1404, and in the reign of King Henry the Fourth of England, an act was passed in order to restrain in some degree the knavery and trickery which abounded amongst professors of the art of alchemy. Even oculists will admit that there is no passion which so effectually blinds its votaries as that of avarice; and during the fifteenth and seventeenth centuries every clever trick that the ingenuity of man could devise was practised for the purpose of simulating the transmutation of the base metals into gold and silver. Numbers of books were written alleged to be translations of the works of Hermes, Geber, Roger Bacon, and other great men, who would have blushed that such nonsense should be imputed to them; and even when the commonest things were mentioned, they were concealed by anagrams or put into the most fantastic diagrams like the next cut (Fig. 83), which is taken from the "Theatrum Chemicum Britannicum," by Elias Ashmole. This picture is supposed to be explained in the following verses belonging to "Ripley's Scroule":—

ON the *Ground* there is a *Hill*,
Also a *Serpent* within a *Well*:
His Tayle is long, with wings wide,
All ready to fly on every side,
Repaire the well round aboute,
That the *Serpent* pas not out;

For if that he be there agone,
Thou loosest the vertue of the *Stone*.
What is the *Grounde* thou may'st know heere,
And also the *Well* that is so cleere:
And eke the *serpent* with his Tayle,
Or else the worke shall little availe.
The Well must brenne in Water cleare.
Take good heede for this thy Fyre,
The Fire with Water brent shall be,
And Water with Fire flush shall be;
The Earth on Fire shall be put,
And Water with Fire shall be knit;
Thus ye shall go to Putrifaccion.
And bring the Serpent to redaction.
First he shall be Black as any Crow,
And doune in his Den shall lye full lowe;
I swel'd as a Toade that lyeth on ground,
Brust with bladders sitting so rounde,
They shall to brast and lye full plaine,
And thus with craft the Serpent is slaine.
He shall show Collours there many a one,
And tourne as White as wil be the bone.
With the Water that he was in
Wash him cleane from his sin;
And let him drinke a litle and a lite,
And that shall make him faire and white;
The which Whitenes is ever abiding,
Lo here is the very full finishing;
Of the White *Stone* and the Red,
Loe here is the true deed.

Fig. 83. The Illustration to the Alchemical Verses.

In these verses it would appear that *ground* means the earth, on or out of which proceeds a hill, probably Nitre or Saltpetre. This yields the Serpent or Aqua Fortis (Nitric Acid). The latter acid is often confounded in the alchemist's nomenclature with Nitre, sometimes termed the Dragon, a Venomous Worm, a Scorpion devouring his children, whilst Aqua Fortis is distinctly spoken of as Heaven, Dew of Heaven, Celestial Water, Celestial Rain, May Dew, Water of Paradise, Parting

Water, Aqua Regis, a Corrosive Sublimate, Sharp Vinegar, Brandy, Viridescent Water, Leo Viridis (the Green Lion), Blood, Milk, a Fiery-burning Spirit, a Deadly Poison and Basilisk, a Vulture, the Bird of Hermes, and alluded to by many other absurd names.

The "*Well* that is so cleere" means some glass vessel; it must "brenne" or "heat in water cleare," *i.e.*, it must be placed in a water bath, of which the alchemists make frequent mention, and depict over and over again in their works on alchemy. By the aid of the serpent "ye shall go to

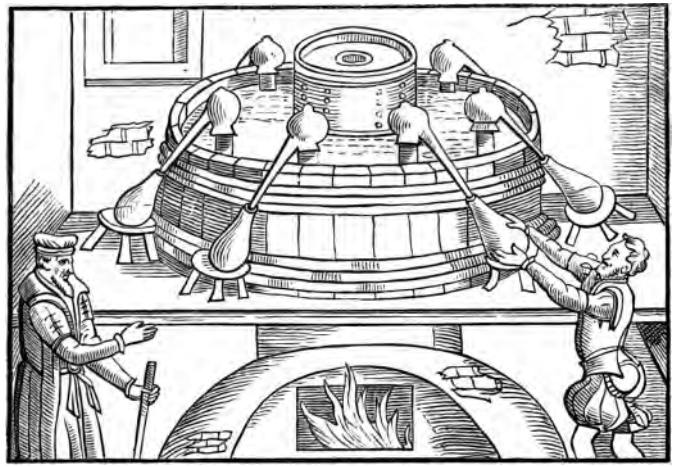


Fig. 84. The Water-bath containing Alembics, which are connected with Receivers for the Distillation of Aqua Fortis.

Putrefaccion," *i. e.*, Silver and Gold may be attacked by the double-headed serpent, or Aqua Regia, from which the White Stone, probably Chloride of Silver, and the Red Stone, Chloride of Gold, would be procurable. The Silver is represented by the Moon, whilst Gold is shown by the Sun, so that these verses and the picture (Fig. 83) merely allude to the effect of Aqua Regia upon the precious metals gold and silver.

Having sufficiently illustrated the jargon of the alchemists, we may now explain how they apparently performed transmutation.

During the sixteenth and seventeenth centuries the practice of alchemy had risen to the highest pitch, and men of learning, princes, and even kings, whose education should have taught them better things, were all infatuated with the art from which the ban of Henry the Fourth had been partly removed by an act of the imbecile Henry the Sixth, from whom letters patent were granted to several persons, by which they were permitted to investigate a universal medicine, and to per-

form the transmutation of metals into real gold and silver, with a *non obstante* of the previous statute, which remained in full force till the year 1689, when the famous Robert Boyle by his interest succeeded in obtaining its repeal, because the act was supposed to operate to the discouragement of the melting and refining of metals.

At the time that alchemy flourished as a thriving trade, nothing was more common than to find men in the garb of beggars who professed to be alchemists. Such persons made their way through the towns and villages, and quietly eased their avaricious dupes of all they could squeeze out of them, the victims generally being ashamed to complain openly of their losses, fearing the ridicule of their fellow-townsmen. Had all men possessed the discernment of Pope Julian, the pretended alchemists would have had but a sorry trade. When the Pope was canvassed by some fellow who undertook to make his fortunes by transmutation, if supplied with a little *ready money* to go on with, his Holiness presented him with an *empty purse*, remarking that of course the possessor of *the secret* could easily fill it. Sometimes an apparently rusty old iron nail and a bottle of wonderful elixir would be displayed; a few cabalistic high-sounding words were solemnly uttered, the nail was stirred in the elixir, and now gold flashes on the eyes of the delighted and credulous beholders! The nail is handed round for inspection, and

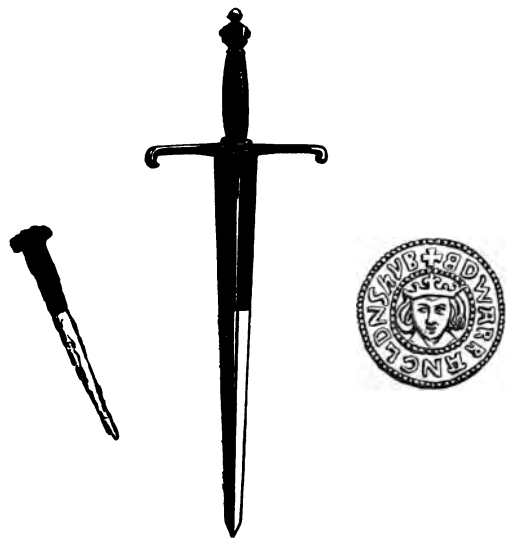


Fig. 85. The Nail, the Dagger, and Coin used by pretended Alchemists.

found to be changed to gold where it had been immersed in the elixir; but of course the small quantity of fluid in the hands of the alchemist had lost its power. Some more could be made, and money was necessary to buy the apparatus and chemicals. When these funds were provided, the impostor decamped, taking with him his prepared nail, half iron and half gold, the whole being painted to represent common iron, so that when the nail was stirred in the elixir (*i.e.* water) the liquid removed the outer covering of paint, and the gold appeared. It is really surprising that men could be found sufficiently bold to attempt the trick, or others dull enough to believe in it; but there is evidence of such nails being used, and one is still preserved in a cabinet of curiosities belonging to the "Grand Duke of Tuscany." A monk presented a dagger of a similar construction to Queen Elizabeth of England, the blade of which was half gold and half steel, and alleged to have been produced by transmutation. Coins, prepared in a similar manner, one face being made of gold and the other of silver, were also shown to the credulous as proofs of *the art*. (Fig. 85.)

Another simple mode of conjuring, or conveying by sleight-of-hand, gold or silver into a crucible, called at the time transmutation, was that of using a hollow rod, which, being previously filled with bits of gold or silver, and closed at one end with wax, would, of course, deliver the

Fig. 86. The Miraculous Omelette from the Monk's Wand.

same into the crucible, when the heat had melted away the wax. Indeed, this is perhaps one of the oldest tricks, and finds its parallel in the pious fraud of the good Spanish monk, who produced an omelette in a frying-pan out of his staff for one of his hungry flock, having previously conveyed therein the materials usually employed in the preparation of that culinary delicacy.

The best mode of carrying out the deception of "projection" is that which the dishonest alchemist (pretending to avoid even the appearance of trickery), might put into the hands of his credulous employer, and say with apparent frankness and love of fair dealing, "Take my crucible and make it red-hot; pour in some quicksilver, and then throw on the powder of projection. I will not *stay* with you or *approach* the furnace whilst the philosopher's stone is being applied; attend to my directions, and the mercury shall be turned to gold." The willing captive of his own imagination obeys; the projection is finished; nay, the crucible taken from the furnace, cooled, and broken, and now the precious morsel falls out—gold!—yea, pure gold! The deception, however, is soon explained; a lump of gold is first melted in a crucible, and allowed to cool so as to take the shape of the bottom of that earthen vessel. This gold is then transferred to a new crucible, and neatly bedded in and concealed by clay, with which the whole is more or less plastered. When this prepared crucible is shown in a red-hot state, the interior lining is not detected, and if the clay has been nicely worked and mixed, it will prevent the mercury which may now be poured in from indurating the surface of the gold, and also protect it from the action of the sulphur of the red fire, which, of course, must be the powder of projection;

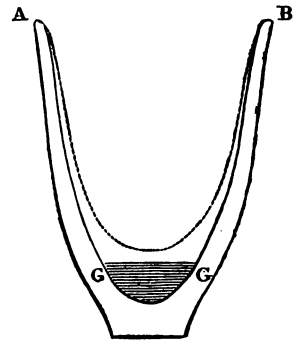


Fig. 87. G G. Lump of Gold filling the Bottom of the Crucible, A B. The space within the dotted lines indicates the clay used to conceal the gold in A B.

when this latter has deflagrated, and the whole is left sufficiently long in the furnace to volatilize the mercury, then the crucible may be taken

out, cooled by immersion in water, and broken; and of course, the lump of gold will fall out. Sometimes they drilled holes in lumps of lead, into which they poured molten gold; the holes were then stopped with other bits of lead, and when placed in a crucible and subjected to calcination and proper treatment on the cupel, the lead was gradually oxidised and removed, whilst the gold remained. Even the schoolboy's trick of washing coins with mercury was not thought too shallow for the deception of the uninitiated. A gold coin amalgamated with mercury looks somewhat like silver, but rings with a deadened sound. The pretended alchemists soon transmuted it back to pure gold by boiling it in aquafortis, which dissolved the mercury, but did not touch the gold.

The author remembers a case where he was applied to for advice, after several hundred pounds had been expended on a modern alchemist who undertook to make gold. Upon examination of one flask alleged to contain the precious metal in process of manufacture, it proved to be nothing but fragments of mica in a yellow fluid, and as they were shaken about, they glittered and looked like gold. After pouring off the fluid, the white and colourless mica was apparent. Another bottle alleged to contain the seed of gold, turned out to be partly filled with corrosive sublimate. Whilst some bits of a crucible containing a few specks of gold, stated to have been procured by projection, appeared to be the result of an unsuccessful attempt to fuse together some finely-divided gold, prepared by precipitating a solution of the chloride of gold with one of sulphate of iron.

The chief alchemists who distinguished themselves in the sixteenth and seventeenth centuries were Augurello, Cornelius Agrippa, and Paracelsus. The latter was undoubtedly a man of genius, but, unfortunately, the lustre of his talents was greatly dimmed by the most outrageous vanity, which displayed itself in empty boasts and bombastic assertions. We are so accustomed to hear that the lion was as meek as a lamb, and *vice versâ*, that it becomes an odd coincidence when we find name and character so nicely corresponding as they did in the case of Paracelsus, whose true name was Hohenheim, to which were prefixed the baptismal names of Aureolus Theophrastus *Bombastes* Paracelsus. He affirmed that he had learnt the art of transmutation, and was also possessed of the elixir vitæ, and it is said that he died in consequence of drinking too freely of this remedy against old age, which proved to be strong distilled alcohol (Fig. 92); on the other hand, it is asserted that he died, in a state of abject poverty, in the hospital of the town of Salzburg, in the year 1541.

After Paracelsus came George Agricola, Denis Zachaire, Dr. Dee, and Edward Kelly. These two men were certainly curious examples of learning, enthusiasm, and imposture combined. Kelly appears to have been a firm believer in alchemy, but an unmitigated scoundrel; whilst Dr. Dee was half crazed with his belief in alchemy, and also in his crystal of a convex form, which he alleged had been presented to him by no less a person than the angel Uriel. Dr. Dee believed in a form of spirit-rapping, or the possibility of communicating with the spirits of the invi-

sible world, and supposed that he had only to look intently into his crystal to behold those who had been long dead, and to converse with them.

Fig. 88. Dr. Dee consulting his Crystal, and Kelly in another part of the room digesting the pretended revelations as Dr. Dee delivered them.

How he could look *into* the stone it is impossible to say, considering that the crystal (so-called), was a polished piece of cannel coal, and is thus described in the supplement to Granger's "Biographical History." "The black stone into which Dee used to call his spirits was in the collection of the Earls of Peterborough, from whence it came to Lady Elizabeth Germaine. It was next the property of the late Duke of Argyle, and is now Mr. Walpole's." It appears upon examination to be nothing more than a polished piece of cannel coal. In Mr. George Robins' catalogue, 1842, of the contents of Strawberry Hill, collected by Horace Walpole, we find the following puff:—

"One glance must be allowed at the little glass case in the corner, which is filled with curiosities. Here is the wondrous speculum of the renowned Dr. Dee—the mirror which

'Kelly did all his feats upon.'

A piece of highly-polished cannel coal of a circular form with a handle to it. It is a very mysterious-looking object, and worthy of being called 'The Devil's looking-glass.'"

Fig. 89. Strawberry Hill.

Elias Ashmole, in his notes to the "Theatrum Chemicum Britannicum," states, "It is generally reported that Dr. Dee and Sir Edward Kelly were so strangely fortunate, as to finde a very large quantity of the elixir in some part of the *Ruines* of Glastonbury Abbey, which was so incredibly *Rich* in *vertue* (being one upon 272,330), that they lost much in making *Projection* by way of *Trial*, before they found out the *true height* of the *Medicine*." Ashmole may well say *strangely* fortunate; and he might have added, but unfortunate in the end, for Kelly died whilst endeavouring to escape from a prison in Germany, and Dr. Dee died in 1608, at Mortlake, almost in absolute penury. The nativity of Kelly cast by Dr. Dee is still extant. The document is quoted by Ashmole, and it very much resembles the scrolls which were displayed to the ignorant by the swindling alchemists of the period as proofs of their knowledge of the art of transmutation.

The reason these two swindlers selected Glastonbury Abbey as the place where they pretended to have discovered the elixir was on account of the legend of St. Dunstan, who was born at Glastonbury; he became abbot, and died Archbishop of Canterbury, A.D. 988. "The legend of St. Dunstan," says Hone, "relates many miracles of him, the most popular of which is to this effect: that the abbot, as the fact really

was, became expert in goldsmith's work; it then gives us a story that, while he was busy in making a chalice, the devil annoyed him by his personal appearance, and tempted him; whereupon St. Dunstan sud-

Fig. 90. The Legend of St. Dunstan.

denly seized the fiend by the nose with a pair of iron tongs burning hot, and so held him, while he roared and cried till the night was far spent."

On examining nearly all the stories of alleged transmutation, it will be found that the pretended alchemist never repeated projection more than once or twice, either because all his gold dust was gone, or from fear of detection, and that he invariably disappeared soon after the trick had been performed.

When Dr. Dee and Kelly had ceased to astonish the world, Alexander Seton (supposed to have been the author who wrote under the name of the Cosmopolite) became celebrated. After the death of Seton, Michael Sendivogius, The Rosicrucians, Jacob Böhmen, Peter Mormius, Joseph Francis Borri, who died in the year 1695, made themselves names as remarkable alchemists; but a new light was gradually coming into the minds of the honest alchemists, the printing press had distributed some considerable knowledge throughout Europe, the mysteries and fanciful ideas of the believers in transmutation were giving way to the realities and ingenious experiments of the real working philosophers. In England, Hooke, Mayow, Boyle, Hales, and Sir Isaac Newton had made their names illustrious. In Paris Le Fèbre and Lemery were working zealously at chemical, not alchemical experiments. In the Netherlands and Germany, Van Helmont, Kircher, Boerhaave, Beccher, Stahl, and Glauber made many interesting discoveries in physics and chemistry.

The last of the alchemists were Helvetius, Jean Delisle, Albert Aluys, the Count de St. Germain, and the arch-quack Cagliostro, who died in the year 1790, a prisoner in the Castle of St. Angelo. "The Chemist" states that, "even as late as the year 1784, Dr. Price, the author of a 'History of Cornwall,' a physician and a member of the Royal Society, publicly proclaimed that he could make gold, and had made it in the presence of several persons; he even presented some of it to the King. The Royal Society, however, empowered the celebrated chemist, Mr. Kirwan, and the alchemist Woolfe to examine into the pretensions of the doctor, and he was obliged to submit to the trial. He first of all excused himself by saying he had employed all the powder in the first attempt, but was compelled by reproaches to begin the task. In this stage his art forsook him; with anxiety he endeavoured to convert mercury, by means of phosphoric acid, into silver; he performed experiments which consisted in treating arsenic with volatile alkali, and what is called the Constantine experiment. All failed, and he was called on to make some more of his powder. After an uninterrupted labour of six weeks, he made his will, distilled for himself a pint of laurel-water, drank it, and died in half an hour, at the age of twenty-six, a martyr to a delusion that, even were it realized, would have no value, nor be of any utility. He was a man of great talents, but of greater ambition, and aimed at the *reputation* of being the *greatest genius* of the age. He was possessed of considerable property, but wrecked his happiness and lost his life by being so credulous as to believe the assertions of the alchemists."

Whilst alchemy was slowly passing away, and chemistry taking its place, the transition state was plainly evident in the books of some of the most industrious workers in the laboratory. This intermediate state of the science is very evident in the works of the celebrated Glauber, who discovered the process of procuring vinegar, or acetic acid, by the destructive distillation of wood; also the method of procuring the spirit of salt, muriatic or hydrochloric acid from the distillation of common salt and oil of vitriol; likewise the preparation from the

caput mortuum (or residue, after the muriatic acid was distilled off) of the sal mirabile, or Glauber's salt, now more correctly termed sulphate

Fig. 91. Glauber's Method of procuring Acetic Acid by the destructive Distillation of Wood, copied from his "Miraculum Mundi." "A is the Furnace or oven, wherein the wood is char'd. B. The Cover of the Furnace. C. The door at which the coals are taken out. D. The Canes or Pipes wherein the sap or juice of the wood is condensed, and from thence runs into the receiver. E is the vessell or receiver into which the vinegar of wood runs."

of soda. Glauber also discovered that a volatile alkali could be obtained by the distillation of bones, and that, by admixture with his spirit of salt, sal ammoniac was procurable; he also distilled sulphate of ammonia with common salt, and obtained common sal ammoniac. These important discoveries show that Glauber was something more than a mere alchemist, and his large work, containing "Great Variety of Choice Secrets in Medicine and Alchymy in the Working of Metallick Mines and the Separation of Metals; also Various Cheap and Easie Ways of Making Salt Petre, and Improving of Barren Lands and the Fruits of the Earth; *together with many other things profitable for all Lovers of Art and Industry.* Translated into *English,* and published for *Publick Good* by the *Labour, Care,* and *Charge* of Christopher Packe, Philochymico-Medicus," date 1689, is well worthy of inspection; and, though encumbered with several ridiculous processes for making gold, still contains many important recipes, from which we make an extract:—

"*Cabinet-makers may strike an excellent Black upon Pear-tree, Cherry-tree, Box, Walnut-tree, and other hard Woods, which may be used for curious work instead of Ebony. Skinners or Furriers may dye their Ermines, Fox-skins, Wolf-skins, and the like Furs with a scarlet, crimson, or deep black colour, far exceeding the natural. In like manner, Feather-dyers may swiftly give any lasting colour to their plumes.* If an *Aqua-fortis* be distilled from Niter and Vitriol, and a little Silver dissolved in it, and Rain water poured thereon (for the weakening of the *Aqua-fortis*), then not only all hard woods are blackened by it, so that they represent Ebony, but also skins and feathers are made black as a coal, a ground being first laid upon the feathers, skins, or woods, that the colours may remain and endure firm."

If Glauber had only applied his solution of nitrate of silver as a "hair-dye," he would doubtless have realized a large sum of money; and long after his time, and at least two hundred years subsequently, photography has almost entirely usurped the use and application of nitrate of silver in the arts.

The latter part of the eighteenth century is remarkable for the brilliancy of the talents of those who made the science of chemistry their study. On the 1st of August, 1774, Dr. Priestley made the discovery of a new air derived from red precipitate, a red oxide of mercury; the same metallic compound which Prince Geber had discovered centuries before, and called the calx of mercury. In accordance with the *Phlogistic* theory of Stahl, Priestley called the new air "Dephlogisticated air," it was not, however, the first gas discovered, because Priestley had already made himself acquainted with the properties of nitrous oxide, or laughing-gas; Dr. Black had likewise discovered the properties of carbonic acid or "fixed air;" and the peculiarities of "inflammable air," or hydrogen, had long been known, and first accurately described by Cavendish in the year 1766. Still oxygen was the starting-point, the basis of an entire new system of chemistry; and as this discovery of Priestley was followed up by the original experiments of Cavendish and Watt, and the discovery of the chemical composition of water, the key was inserted into the lock which had so long excluded the philosophers from the abode of Truth; and the nature of air and water being once understood, experiment, reason, and analogy have done the rest, and in about ninety years brought the science of chemistry to its present wonderful development. Black, Cavendish, Watt, Priestley, Bergman, Scheele, were the celebrities who worked in the dawn of chemistry. "Among the brightest names," says Fownes, "which adorn the annals of chemical science will ever be placed that of Lavoisier, who at the period of the discoveries of Priestley and Cavendish pursued his researches in France. To call Lavoisier the Nestor of chemistry would scarcely be a profanation of that honoured name. The new facts he actually discovered were not remarkable; it was his surpassing power of generalization, his acuteness in distinguishing between the essential and the accidental phenomena he witnessed, in his careful and happy repetition of the experiments of others, which distinguished him above all who

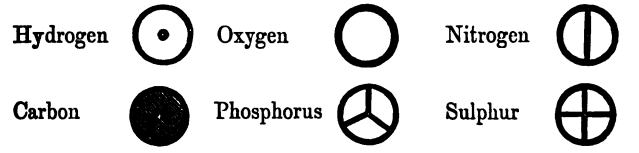
went before. To point out the *elementary nature* of the *metals*, and show the fallacy of the evidence upon which the opposite view was founded; to explain clearly the nature of the metallic oxides and the composition of salts, were indeed great works. The reform of the nomenclature was chiefly the work of Lavoisier; and this nomenclature, after the lapse of more than half a century, is still adequate to the wants of the science, because its principle is sound and philosophical, and capable of indefinite expansion. To complete the catalogue of the obligations we owe to this great man, it may be said that he created the art of *quantitative research*. An appeal to the balance was Lavoisier's habitual argument; it was his infallible guide, his just and most faithful judge."

How sad to reflect that this great and shining light was quenched in the horrors of the French Revolution, and that the name of the elegant and accomplished Lavoisier was inscribed in the fatal list *Fermier-Général*, No. 5, and that he perished on the 8th of May, 1794.

Having traced out by rapid steps the rise and fall of alchemy and the foundation of chemistry, it is impossible, without seriously interfering with the object of these pages, to pursue the subject further. We may, however, pay a passing tribute to the names of Wenzel, Richter, Sir Humphry Davy, Dr. Wollaston, and, above all, to that of Berzelius, whose name we shall frequently observe to be associated with the metals and their combinations. Berzelius has been truly called one of the patriarchs of analytical chemistry. The tables of *equivalents*, or combining quantities of matter by weight, which we now possess, have chiefly been the result of the labours of this great chemist. It is, however, to Dr. Dalton that we are indebted for the first distinct anticipation, founded on well ascertained facts, of the general law of multiple combination, and for *The Atomic Theory of the Chemical Constitution of Bodies*. As the alchemists designated their metals by peculiar signs, so Dr. Dalton represented the elementary substances and chemical combinations by characters which have not, however, come into use. The system that merely gives the initials of the elements and the number of their atoms being preferred from its extreme simplicity, although Dalton always contended that his own plan of representing the probable position of the atoms of a compound was preferable. "Taking for granted," remarks Dr. Henry, "that combination takes place between the atoms of bodies only, Dr. Dalton has deduced from the *relative* weights in which bodies unite, the relative weights of their ultimate particles or atoms. This is all that we are likely to determine respecting them; for it is not probable that our knowledge will ever extend beyond the *ratios* of these weights. When only one combination of any two elementary bodies exists, Dalton assumes, unless the contrary can be proved, that its elements are united atom to atom singly. Combinations of this sort he calls *binary*. But, if united compounds can be obtained from the same elements, they combine, he supposes, in proportions expressed by some simple multiple of the number of atoms. The following table exhibits a view of some of these combinations according to Dalton's theory:—

"1 atom of A + 1 atom of B = 1 atom of C, binary.
1 atom of A + 2 atoms of B = 1 atom of D, ternary.
2 atoms of A + 1 atom of B = 1 atom of E, ternary.
1 atom of A + 3 atoms of B = 1 atom of F, quaternary.
3 atoms of A + 1 atom of B = 1 atom of G, quaternary."

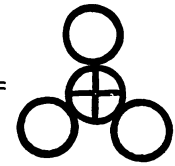
The characters Dalton used may be copied from one of his own diagrams in Dr. Henry's "Life of Dalton," from which we have also taken the portrait that heads the next chapter. The elements were designated by special characters, as in the following examples:—



A Binary compound, such as water . . . . =

A Ternary compound, such as carbonic acid . =

A Quaternary compound, such as sulphuric acid =



By the system now in use water would be represented briefly by the letters HO; carbonic acid, CO_2; and sulphuric acid, SO_3.

With regard to the appreciation of the labours of Dalton by other and foreign distinguished chemists, the following letter, dated September 20, 1853, from Baron Liebig to Dr. Henry, author of the "Life of Dalton," speaks volumes:—

"You wish to have from me my view of the hypothesis of Dalton, and of its influence on the development of chemistry. This is a difficult problem; for we, who stand in presence of the science as now constituted, can scarcely conceive how it would have developed itself without this hypothesis. All our ideas are so interwoven with the Daltonic theory that we cannot transform ourselves into the times when it did not exist. Dalton's atomic theory was a product of the age, and sprung forth in his mind as a consequence of the discovery of chemical proportions or equivalents. By means of this theory, the numerical results were marked with definite representations concerning the internal

nature and constitution of chemical combinations; and thus a number of researches were called forth and prepared for, which had for their object the relations of physical properties to internal composition. I need refer only to isomorphism, to the relations of the specific heat, to the atomic weight, and to those of the boiling point to composition. Chemistry received in the atomic theory a fundamental view, which overruled and governed all other theoretical views to which the ideas of the age respecting chemical forces, affinity, cohesion referred themselves; it was the bond which bound together all other views. In this lies the extraordinary service which this theory rendered to science, viz., that it supplied a fertile soil for further advancement—a soil which was previously wanting. In the most recent investigations concerning the constitution of organic bases, the alcohols and the acids corresponding to the alcohols, we have seen that the groundwork of the Daltonic theory is equally valid for organic bodies. His main law that the properties of compounds are dependent on the nature of their elements, and on the mode and way of their position or arrangement, will always maintain a high value."

Fig. 92. The Death of *Bombastes* Paracelsus by drinking Alcohol, being his alleged *Elixir of Life*.

Fig. 93. Bust of Dr. Dalton, from the Statue by Chantrey.

CHAPTER III.

THE METALS AND THEIR COMBINATIONS.

It has already been stated in the Introduction to this work that the thirteen non-metallic elements were considered in a popular manner in the "Boy's Playbook of Science," and that the pure metals, or metallic elements, would conclude the description of the whole series of elementary bodies at present known. The metallic elements are about fifty-one in number, and their names, discoverers, symbols, and equivalent numbers are enumerated in the next table.

Name.	Derivation of name.	Symbol.		Equivalent or combining weight.	Names of eliminators.
		Ancient.	Modern.		
1. Aluminium...	*Alumen*, alum: Latin, but of Greek extraction	...	Al	13·7	Wöhler.
2. Antimony ...	*Anti*, against; *Monos*, one: Greek words	♁	Sb	129	Basil, Valentine
3. Arsenic... ...	*Arsenicon*, potent: Greek ...	o—o	As	75	Brant, possibly Paracelsus.
4. Barium... ...	*Barus*, heavy: Greek	...	Ba	68·5	Davy.
5. Bismuth ...	*Weiss Muth*, white matter: German	B	Bi	213	Agricola.
6. Cadmium ...	*Cadmeia*, calamine: Greek...	...	Cd	56	Stromeyer.
7. Calcium ...	*Calx*, lime: Latin...	...	Ca	20	Davy.
* 8. *Cerium*... ...	*Ceres*, planet so called: Latin	...	Ce	47	Hisinger and Berzelius.

* *The names of* the metals which are at present unimportant are printed in italics.

Name.	Derivation of name.	Symbol.		Equivalent or combining weight.	Names of eliminators.
		Ancient.	Modern.		
9. Chromium ...	*Chroma*, colour: Greek... ...	...	Cr	26·7	Vauquelin.
10. Cobalt	*Kobold*, an evil spirit: German	K, ♂	Co	29·5	Brandt.
11. Copper... ...	*Cyprium*, cyprus: Latin ...	♀	Cu	31·7	Known to the ancients.
12. *Donarium* ...	*Donarium*, a gift: Latin ...	...	...	...	.....
13. *Didymium* ...	*Didumos*, twins: Greek ...	...	D	50	Mosander.
14. *Erbium* ...	... ...	...	E	...	Mosander.
15. Gold	Probably from the Hebrew, signifying to be clear or to shine	☉	Au	197	Known to the ancients.
16. Glucinum ...	*Glukos*, sweet: Greek	...	Gl	6·9	Wöhler.
17. Iron	Probably from the Hebrew, signifying to melt	♂	Fe	28	Known to the ancients.
18. *Ilmenium* ...	(Its existence denied)	...	Il	...	Hermann.
19. Iridium ...	*Iris*, rainbow: Latin	...	Ir	99	Descotils and Tennant.
20. Lead	*Molybdos*, galena, ore of lead: Greek	♄	Pb	103·7	Known to the ancients.
21. *Lanthanium*.	*Lanthano*, to conceal: Greek	...	La	47	Mosander.
22. *Lithium* ...	*Lithos*, a stone: Greek	...	Li	6·5	Arfwedson.
23. Magnesium..	*Magnesia*, name of a locality in Asia Minor	...	Mg	12·2	Bussy.
24. Manganese...	*Mangana*, in East Indies ...	...	Mn	27·6	Gahn.
25. Mercury ...	*Mercury*, name of the planet	☿	Hg	100	Known to the ancients.
26. *Molybdenum*.	*Molybdos*, because mistaken for lead: Greek	...	Mo	46	Hielm.
27. Nickel	*Kupfernickel*, false copper: German	...	Ni	29·6	Cronstedt.
28. *Norium* ...	*Nore*, old name of Norway ...	...	...	...	.....
29. *Niobium* ...	*Niobe*, daughter of Tantalus	...	Nb	...	H. Rose.
30. *Osmium* ...	*Osme*, odour: Greek	...	Os	99·6	Tennant.
31. Platinum ...	*Platina*, little silver: Spanish	...	Pt	98·7	Wood.
32. Potassium ...	*Pot-ashes*	...	K	39·2	Davy.
33. Palladium ...	*Pallas*, name of a planet ...	...	Pd	53·3	Wollaston.
34. *Pelopium* ...	*Pelops*, son of Tantalus, substance so called by Osann	...	Pe	...	H. Rose.
35. Rhodium ...	*Rodon*, a rose: Greek	...	R	52·2	Wollaston.
36. *Ruthenium*...	... ...	...	Ru	52·2	Klaus.
37. Silver	Probably from the Hebrew, signifying money	☽	Ag	108·1	Known to the ancients.
38. Sodium ...	*Salsola*, soda, name of a plant	...	Na	23	Davy.
39. Strontium ...	*Strontia*, place in Scotland...	...	Sr	43·8	Davy.
40. Tin	... ...	♃	Sn	59	Known to the ancients.
41. *Tantalum*, or Columbium	*Tantalite*, name of a mineral	...	Ta	184	Hatchett.
42. Tellurium ...	*Tellus*, the earth: Latin ...	...	Te	64·2	Riechenstein and Klaproth.
43. *Terbium* ...	... ...	...	Tb	...	Mosander.
44. *Thorium* ...	*Thor*, ancient deity	...	Th	59·6	Berzelius.
45. *Titanium* ...	*Titans*, mythological deities	...	Ti	25	Gregor and Klaproth.
46. Tungsten ...	*Tungsten*, heavy stone: Swedish	...	W	95	De Luyart.
47. Uranium ...	*Uranus*, name of a planet ...	...	U	60	Klaproth.
48. *Vanadium* ...	*Vanadis*, ancient deity... ...	...	V	68·6	Sefström.
49. *Yttrium* ...	*Ytterby*, locality in Sweden...	...	Y	32·2	Wöhler.
50. Zinc	*Zinken*, nails: German... ...	♎	Zn	32·6	Paracelsus.
51. *Zirconium* ...	*Zircon*, four-cornered: Ceylonese	...	Zr	22·4	Berzelius.

After looking through the table of metals, the inquiring student will naturally ask what are the properties that distinguish the fifty-one metals from the thirteen non-metallic bodies? and this question we shall first endeavour to answer, in order to show why this classification should be insisted on.

In the first place, if we arrange a series of bottles containing specimens of the thirteen non-metallic bodies, we immediately perceive that three only of them—viz., iodine, silicium, and gas carbon—possess the power of throwing off or reflecting light, so as to assume that appearance which is correctly designated as metallic lustre. They all reflect light, but not in the same brilliant degree, as polished gold, silver, copper, zinc, &c. &c. Indeed, there ought to be two kinds of "lustres;" one might be termed the "mineral" and the other the "metallic" lustre. The examples of metallic brilliancy are very numerous; thus, a bit of smooth cannel coal may be covered with leaf-gold which is not more than the $\frac{1}{200000}$th part of an inch in thickness. If the gold-leaf is nicely burnished, it imparts an appearance to the coal which might lead an observer who does not handle the brilliant-looking substance to suppose it may be metallic gold, because coal never possesses a superficial "metallic lustre." Again, glass reflects light, and when cut in the form of a prism, and observed in a particular manner at a special angle, it appears very much like bright shining silver; but glass of any shape may have a brilliant lustre imparted thereto, by attaching to it either a metallic amalgam of tin and mercury, such as is used in the manufacture of looking-glasses, or by precipitating metallic silver from its solution by the processes of Drayton or Hale Thomson. Salt-cellars and other vessels made of glass may be easily mistaken for silver ones when prepared by the latter gentleman's complete and perfect process, because they have metallic lustre arising from the deposit of pure silver. The metal never changes, being placed just as if it were in a well-corked or stoppered bottle, and completely out of contact with the air. A small looking-glass is easily made by laying down a sheet of tinfoil on a smooth surface, composed of wood, slate, or marble; mercury is then carefully dropped upon and gently rubbed into and amalgamated with the tin with some nice soft cotton wool. When the whole surface of the tinfoil is amalgamated, an excess of clear mercury is poured on so as to flood the tin foil, where it remains by cohesion, rising like water from the edge of a glass filled to overflowing. A sheet of perfectly

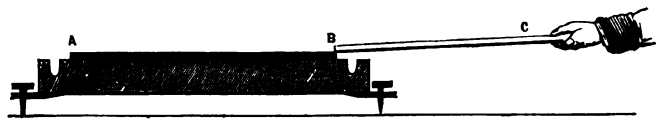


Fig. 94. A B. Tinfoil flooded with mercury, and placed on the levelled stand, with a groove cut round it to catch the excess of mercury. B C. The plate glass held with both hands by the edges, and carefully slidden over the amalgamated tinfoil.

clean plate glass is now gently slid over the edge of the amalgamated tinfoil, so as to remove the excess of mercury and secure contact between the surface of the glass and amalgam. Great care must be taken not to push the glass too roughly over the tinfoil and mercury, or else the latter is liable to crack, and the looking-glass is then imperfect. After the contact has been secured, and all air-bubbles excluded, the silvered glass may be placed on a smooth surface covered with paper or cardboard, and pressed with another board on which weights or heavy books are placed. The excess of mercury is then squeezed out, and after it has been placed on end so as to allow the remaining mercury to fall towards the lowest point, the amalgam becomes sufficiently hard, and the looking-glass may be framed. On the large scale, the table used is made of slate or marble, with a ledge all round, within which is a groove or channel; it is truly levelled, and rests on an axis of iron, which runs through the middle of its length, so that by means of a screw the table can be placed at an angle of twelve or thirteen degrees, in order to allow the excess of mercury to run off. Of course great care and skill must be used so as to lay down the separate sheets of tinfoil side by side, to amalgamate the whole, and then to slide the great sheet of plate glass gradually over the mercurialized surface. The plates of glass sometimes break with the pressure required; the amalgam also will occasionally crystallize, and spoil the reflecting surface; or a drop of mercury will flow down from the top when the glass plate is put on end to drain, and give rise to curved streaks called "*worms*," in consequence of small portions of the amalgam being carried away by the drop of falling mercury. Moreover, the effect of the mercury on the health of the workmen is very prejudicial, producing what is termed "a fit of the trembles;" and "if," says a writer in the "Edinburgh Review," "the charming belle, as she surveys her beauty in the glass, could but for a moment see reflected this poor shattered human creature with trembling muscles, brown visage, and blackened teeth, she would doubtless start with horror; but as it is, the slaves of luxury and vanity drop out of life unobserved and uncared for, as the streams of travellers disappeared one by one through the bridge of Mirza."

Silvered glass mirrors, in the literal sense of the word, have therefore been proposed, and the patented processes of Drayton and Thomson have been worked apparently with little success, in consequence of the cost and defects of the silvered surfaces as compared with those prepared with the amalgam of tin and mercury. Drayton's process of silvering is conducted in the following manner:—A sheet of clean plate glass is surrounded by a rim of putty, and a thin layer of silvering fluid poured on. The solution consists of one part of nitrate of silver, to which enough ammonia has been added to precipitate and nearly dissolve the whole of the oxide of silver. This solution is then filtered, and if one ounce of nitrate of silver has been used, three ounces of alcohol containing twenty or thirty drops of oil of Cassia must be added to it, and the whole shaken together and poured on the surface of the glass, or the silver solution may be poured on the glass first, and the alcohol

and oil of Cassia afterwards. The fewer the drops of oil of Cassia, the slower and more perfect is the deposit and brilliancy of the silver, of which from twelve to eighteen grains will cover a square foot of glass, whilst the value of the silver covering a surface of ten feet by five feet, varying from $\frac{1}{2500}$th to $\frac{1}{1700}$th of a line in thickness, is stated not to exceed from seven to ten shillings. Mirrors silvered by the deposit process are not, however, popular with the manufacturers, because they become spotted, and present a black aspect which is not considered flattering to the visages of those who have occasion to consult their looking-glasses. The best way to show the process is to cork one end of a long clean glass tube, and then to pour in the silvering solution. When the silvering is complete, pour away the solution, and wash out any adhering portions of the oil with spirits of wine; drain, dry, and cork the tube. A number of other deoxidizing agents will answer the same purpose as the oil of Cassia, such as tannin, grape-sugar, &c.

Fig. 95. Red-hot Iron Ball on the palm of the Hand, protected by some powdered charcoal.

The property of opacity is conjoined to that of metallic lustre, although gold leaf of the thickness already alluded to will transmit a greenish light.

It has been shown that the metals are remarkable for their metallic lustre and opacity; they are also distinguished as good conductors of heat, whilst the thirteen non-metallic bodies are bad conductors. A red-hot iron ball may be placed for a short time close to the skin of the hand, provided a thin film of charcoal is interposed, because the latter is a bad conductor of heat; but if iron or other metallic filings are substituted for the charcoal, the effect of the conducting power of the metal is soon apparent, and the red-hot ball must be quickly removed.

The relation of heat generally to the metals is peculiar and interesting. The celebrated Dr. Black, in one of his lectures, says, "I therefore consider the metals as substances which have the power to retain strongly a certain quantity of *latent* heat, which gives them their toughness and malleability; but I imagine that heat is driven out of them by the violent agitation, compression, and friction of their parts in hammering them strongly into another shape. Those called the more perfect metals retain this heat with the greatest force, and retain it in some cases, though extended by skilful hammering to an amazing degree. Tough iron, which is a purer metal than steel, contains more of it than steel does, and shows a little more power to retain it; from iron it cannot be expelled but by the strokes of the hammer, or violent compression; from steel it can be separated not only by hammering, but also by

sudden and violent refrigeration of the steel from the red-hot state. This happens in the operation called the hardening of steel. The steel is made red hot in the fire, and then suddenly plunged into cold water. Thus it is made excessively hard, but, at the same time, perfectly flexible or brittle. We must, therefore, conclude that this sudden and violent refrigeration prevents its retaining a due portion of latent heat, which it would have retained, had it been allowed to cool slowly and quietly. Iron, when treated in the same manner, loses very little of its latent heat."

The quantity of latent heat in the metals is curiously illustrated by the flash of faint light which is apparent when a bullet from Perkins's steam-gun strikes a wrought-iron target. The bullets are completely flattened, and when directed against a plate of lead placed in front of the target a "cold weld" takes place, the two surfaces of lead being firmly united, as if melted or soldered together. The flash of light is not visible during the daytime, and only in a darkened room. Another most interesting example of the latent heat retained by metals, and especially iron, was demonstrated during the trials of Mr. Whitworth's 80-pounder flat-headed hexagonal bolts—we cannot term them balls—against the resistance offered by the thick iron sides of the floating battery *Trusty*. Previous experiments had shown that a single ball from the smooth bore 68-pounder, or from Armstrong's famous gun, produced little or no effect upon the plate armour even at a point-blank range of 200 yards. The plate armour is made of slabs of the finest wrought iron 4½ inches thick, which is backed up and further strengthened inside by 22 inches of oak or teak beams laid transversely, and with half an inch of wrought-iron plate inside them again; but, notwithstanding the immense resisting power of the iron plates, the hexagonal

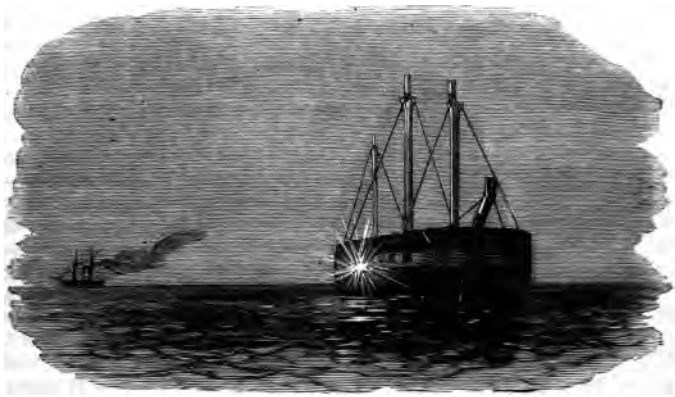


Fig. 96. Whitworth Gun and the Iron-plated Floating Battery, the *Trusty*, showing the flash of light when the shot struck the side.

80-pounder flat-headed bolt, projected from a cannon also made by Mr. Whitworth, passed completely through them when fired with a charge of fourteen pounds of powder. The hole it made in the plate was a clean hexagon, precisely the size of the shot. *The shot, when found, was so hot that no one could touch it.* It scarcely showed any sign of damage beyond being compressed to about an inch shorter. The fifth shot again pierced through the centre of a plate and into the main deck of the ship, driving before it a mass of splinters and an immense iron bolt, which, from the position in which it was found—among the fragments of wood on the main deck—had evidently been dashed through and whirled about with a force only inferior to that of the projectile itself. "*It was noticed that, at the instant of concussion between this shot and the vessel's side, a broad sheet of intensely bright flame was emitted, almost as if a gun had been fired from the* Trusty *in reply.*"

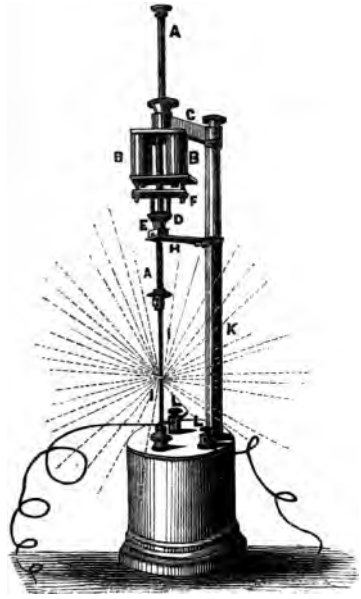


Fig. 97. The new Electric Lamp, invented by Hart, of Edinburgh, is represented by the prefixed figure, and consists of A A, a moveable brass rod roughened on the surface like an ordinary rat-tail file, and holding within its grasp the upper rod of charcoal, I, which constitutes one of the electrodes or poles of the galvanic battery. B B are the two extremities of a soft iron bar covered by insulated copper wire, and forming an electro-magnet when a current of electricity traverses the wire. E is a hollow circular wedge of a conical shape, divided longitudinally into halves, which are hinged to a common basement, and naturally tend to fall outwards. D is a ring surrounding the hollow wedge E, and attached to the armature, F, of the electro-magnet. K is a hollow stem with one arm C, which serves as a support to the electro-magnet, and a second arm, H, which acts as a rest for the hollow wedge. L L are binding screws which connect the wires of the battery with the lamp. I I are the two charcoal pencils which constitute the poles of the battery, between which the light is produced.

Metals are likewise excellent conductors of electricity, whilst the thirteen non-metallics are non-conductors, with the exception of some kinds of carbon, which, in its purest form—viz., the diamond, with a specific gravity of 3·5 to 3·55—is a non-conductor of electricity, whilst in its softer state as in gas carbon, specific gravity 1·76, it is an excellent conductor of electricity, and is employed as the terminals of the copper wires from the voltaic battery to produce the electric light (Fig. 97). The expression of "non-conductor" is useful to employ in an elementary work like the present; but must of course be taken in a qualified sense, and should be,

properly, "bad conductor," as Faraday has shown that good and bad conductors have certain electrical properties in common, and pass by insensible gradations one into the other.

One of the most important physical properties of the metals is their *malleability* or power of extending, without disintegration, when struck with the blows of a hammer. The noble metals, gold and silver, enjoy this property in the highest degree. Ordinary gold leaf is sometimes beaten so thin that five grains will nearly cover a surface of two square feet. Pliny informs us that gold was beaten to such a degree of thinness, that one ounce of gold was extended to 750 leaves, each four inches in size. Lucretius compared the Roman gold leaf to a spider's web; and Martial described it as little other than a vapour. Pliny also states that gold leaf was applied to marble with a varnish, and to wood with a cement called leucophoron. This property of the metals, as compared with non-metallic substances, is easily shown by casting a bar of lead, and then having cooled it to a temperature of 32° Fah., it may be hammered out on the anvil; whilst all the solid non-metallics, if cooled to the same temperature, in order to be able to include phosphorus, are brittle, and easily broken up or powdered.

All the metals, however, are not malleable, and

Arsenic	Manganese
Antimony	Molybdenum
Bismuth	Tellurium
Cerium	Titanium
Chromium	Tungsten
Cobalt	Uranium
Columbium	Rhodium

with some others, are specially to be noticed for brittleness, and the ease with which they may be reduced to powder. The malleability and ductility of metals are strangely altered when they are alloyed together; if no chemical change or union occurred between them, it might be supposed that the alloy would have the mean malleability of the two metals, whereas the change of malleability is very curious in some instances. Thus gold is very properly placed at the head of the list of metals which enjoy the property of malleability, but if alloyed with lead in the proportion of half a grain of the latter to one ounce of gold, the whole becomes quite brittle, and may be easily reduced to powder. It is in this manner Mr. Denham Smith supposes that Moses reduced the Golden Calf to powder by first alloying the metal with lead, and it certainly is a much more probable theory than that proposed many years ago by Stahl, who gives the Israelites credit for more scientific knowledge than they probably possessed, and supposes that Moses made sulphuret of sodium, in a solution of which the gold was attacked and dissolved. An alloy of platinum, copper, and zinc, though remarkably ductile and malleable, is rendered brittle by a quantity of iron not exceeding half a grain in four ounces of the alloy. Dr. Henry remarks "that in such cases it has been supposed that a true chemical union does not take

place, and that the newly-added metal is merely mechanically interposed between the particles of the other, the cohesion of which it thus impairs." This explanation, however, can scarcely be admitted as satisfactory; and among other arguments in proof of the existence of chemical union, it may be remarked that gold is rendered brittle by being kept in fusion in the vicinity of melted tin, the vapour of which it seems capable of attracting. Mercury, again, renders various metals extremely brittle, whilst the addition of a very small quantity of sodium to mercury will render it solid, brittle, and crystalline; hence it may be asked why the metals have, in some cases, a greater tendency to crystallize when alloyed with others? does the addition of the foreign metal, such as lead, act as a nucleus around which the particles of the gold crystallize in cooling? A great deal has yet to be ascertained by experiment before we can make the assertion that an alloy is not a chemical combination.

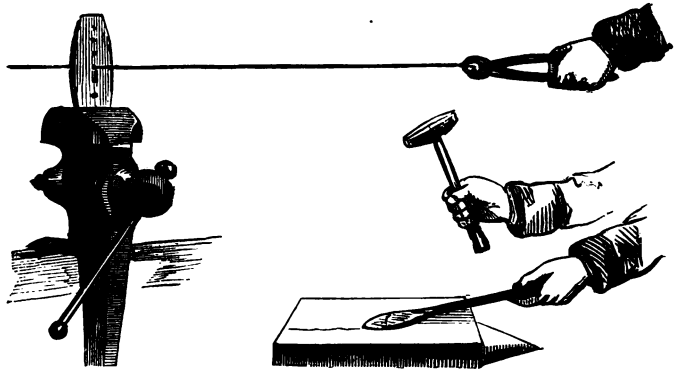


Fig. 98. Illustrations of the Malleability and Ductility of the Metals.

Ductility is quite the twin brother to malleability, and those metals which enjoy the latter property are also remarkable for the possession of the former. Metals are said to be ductile when they can be drawn into thin wire by pulling a circular rod of metal through a steel plate perforated with a succession of holes gradually reduced in size (Fig. 98). The ductility of gold is amazing, and Dr. Halley states that six feet in length of the finest gilt wire, used for lace, brocades, &c., before flattening, will counterpoise no more than one grain, and as the gold is not quite $\frac{1}{57}$th of the whole, a single grain of gold thus extended will be 345·6 feet long. In India the art of drawing gold and silver wire has attained the greatest perfection, and the gold-embroidered housings of the elephant and howdah (Fig. 99) as exhibited by her Majesty in the First Exhibition in Hyde Park, were remarkable examples of the use of gold thread, *i.e.*, silver coated with gold. The Mohammedans of Dacca are

specially remarkable for the Cashmere shawls, scarfs, muslins, and net fabrics which they embroider with silk, gold, and silver thread.

Fig. 99. Embroidered Housings and Trappings of the Elephant and Howdah exhibited by her Majesty in the Great Exhibition, 1851.

Although iron is so tough and hard, it may be drawn into wire as thin as hair, and Dr. Wollaston, by an ingenious modification of the process of gold wire-drawing—viz., by surrounding the gold with silver, and

then dissolving off the latter with nitric acid after the drawing, was enabled to extend one grain of gold to 700 feet. When weights are applied to different metallic wires of the same gauge or diameter, they are found to differ very much from each other in their power of sustaining them. This is called the property of tenacity, or power of resisting a strain. Guyton Morveau has carefully determined the weights which can be supported by wires of a uniform diameter of 0·787 of an English line, without fracture.

A wire of	iron	supports	549·250	lbs. avoirdupois.
,,	copper	,,	302·278	,,
,,	platinum	,,	274·320	,,
,,	silver	,,	187·137	,,
,,	gold	,,	150·753	,,
,,	zinc	,,	109·540	,,
,,	tin	,,	34·630	,,
,,	lead	,,	27·621	,,

One of the most remarkable illustrations of toughness and tenacity is exhibited in the Armstrong gun, of which all patriotic Britons are justly proud. Each gun is made in about three-feet lengths, and on much the same principle as the twisted gun barrels. Thin bars of the best wrought iron, about two inches broad, are heated to a white heat, and in this state twisted and welded together in spiral rolls round a steel bar or core, smaller in diameter than the bore of the gun. Over this, when cold, another twist of the same kind is made, with the spiral running in a contrary direction, and so until three or four layers have been put on, according to the calibre of the gun and the thickness required. The whole is then reheated and welded together for the last time under the steam hammer. The edges of the three-feet lengths are next planed down so as to admit their joining and lapping over, and over these edges are forced on thick wrought-iron rings, which, being welded down at a white heat, of course contract so as to make the joint almost stronger than if made in one piece. In the breech an opening is cut down into the chamber; but the breech itself is separate from the gun, and is worked backwards by a powerful screw.

Unhappy midshipmen, on first joining their ships, are usually favoured by their more hardened shipmates with all the practical jokes that can possibly be played off on them in the narrow sphere of a floating ark; and one of the most dangerous is certainly that termed "cutting down," where the individual in his hammock suddenly gravitates to the hard deck, in consequence of the supporting ropes being cut away; but if some tough iron wires were inserted, and concealed in the ropes, they would still carry the hammock, to the great surprise of those attempting the mischief.

At the theatre the tenacity of copper wire is frequently tested by the ascent of witches, fairies, and other prodigies to the dominion of the carpenters above, termed the "flies." (Fig. 100.)

The standing rigging of ships is now frequently made of iron wire, and wire ropes are continually used for the purpose of traction, either in hauling up coals or minerals from the deepest mines, or, as in the case of the Blackwall Railway some years ago, for dragging the trains backwards and forwards between the drums worked by powerful stationary engines.

Fig. 100. Use of Wire for suspending the Fairies, &c., at the Theatre.

Elasticity is illustrated by the manufacture of iron or steel springs, hardness by the use of steel for cutting tools, or of rhodium for the tips of everlasting pens, sonorousness by the manufacture of steel and silver bells, which are all examples of special physical properties belonging to the metals. Whatever renders metals harder and more elastic

appears to increase their sound-giving power. Another illustration of the change in the properties of the metals when alloyed together, is

Fig. 101. Spiral of Steel for producing the Sound of a Gong.

demonstrated in the manufacture of bell metal, and copper and tin united by fusion, are more sonorous than either singly.

Gold and silver would be too soft, and soon wear out, if they were used for the coinage in a pure state; but the addition of a certain quantity of copper renders them sufficiently hard to sustain the wear and tear of circulation. By the addition of manganese to steel it retains its cutting edge much longer than ordinary steel, and is therefore employed in the manufacture of razors and trade tools. The addition of gold is said to confer even better qualities on the steel than manganese; whilst tungsten, alloyed with steel, is stated to impart such excessive toughness and hardness, that it may be used for boring through steel. Amongst the non-metallic elements carbon in the form of the diamond is remarkable for being the hardest substance in nature; and although certain individual qualities belonging to the metals may be traced to the non-metallics, there is not one of them which it would be desirable to move out of its class. The distinguishing properties belonging to the metals are not, however, confined to the physical ones of brilliancy, malleability, ductility, tenacity, hardness, sonorousness, or to the remarkable power which they possess of conducting heat and electricity.

The metals have peculiar chemical characteristics, viz.:—

A great affinity for oxygen, forming oxides or *bases*, and acids; also
A great affinity for chlorine, iodine, bromine, fluorine, forming salts.

The thirteen non-metallic bodies, with the exception of fluorine and hydrogen, form acids when united with oxygen; but then it must be remembered that hydrogen has been frequently supposed to be a metal, and when united with oxygen forms water, which acts like a base or metallic oxide; for instance, oil of vitriol or sulphuric acid, SO_3HO, consists of dry sulphuric acid, SO_3, and one equivalent of water, HO; but if stated thus it exactly resembles sulphate of soda:—

Hydrated sulphuric acid, or sulphate of water, $HO + SO_3$.
Sulphate of soda. . . . . $NaO + SO_3$.

It will be noticed that in the latter salt the only difference consists in the substitution of Na, *i.e.*, the metal sodium, for H, the gas hydrogen. Other examples might be adduced, but would lead us away from the chief point at present in view, viz., the chemical difference between the two great classes of elements. With respect to the combination of chlorine, iodine, bromine, or fluorine with a metal as compared with a non-metallic element, we may adduce a simple example. Thus, the metal sodium forms with chlorine a salt termed common salt, or chloride of sodium, the type of other salts produced by substituting iodine, bromine, or fluorine for it; hence these four non-metallic elements are sometimes called halogens, or producers of substances like common salt.

Salts.

Chloride of sodium.
Bromide of sodium.
Iodide of sodium.
Fluoride of sodium.

Now, if oxygen is selected as the non-metallic element to be united with these, we have numerous acids formed, such as

Chloric acid, ClO_5.
Bromic acid, BrO_5.
Iodic acid, IO_5.

Fluorine has not yet been united with oxygen gas.

Or, if carbon is taken as an example of the union of a halogen with a non-metallic body, we have a series of compounds with a more or less aromatic odour, such as the

Protochloride of carbon.
Sesquichloride of carbon.
Bichloride of carbon.

Iodine, bromine, and fluorine have not yet been united with carbon.

We might pass through the whole series of non-metallic bodies, and an inquiry into their combination with the four halogens doubtless affords some apparently contradictory facts, but still the line of demarcation is traceable between metallic salts and non-metallic compounds. The strongest title, however, a substance can have to the name of a metal, is its power of uniting with oxygen and forming a *base*. Before a metal can unite with an acid, it must first be oxidized and converted into a base.

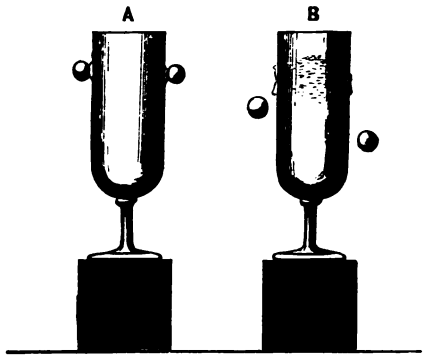


Fig. 102. A. The glass vessel containing metallic zinc and a solution of oxalic acid, with the balls outside. B. The glass containing oxide of zinc and solution of oxalic acid: the heat arising from their union has melted the grease, and the balls are falling.

If some zinc filings and oxalic acid are mixed together and placed in a glass vessel, to the outside of which some large hollow glass beads or light wooden balls have been attached by pomatum, they will not fall off when water is added to the contents of the vessel, because there is no heat arising from chemical combination to melt the grease; but if the same arrangement is made in a second glass vessel, and oxide of zinc, instead of the metal, added to the oxalic acid, then a rapid union ensues between the acid and base, and the heat produced is indicated by the melting of the pomatum and the fall of the little beads or balls.

The act of oxidizing a metal is frequently one of the greatest energy, and usually accompanied with the evolution of much heat. In the respective chapters on these metals it will be observed that iron, lead, copper, &c., in a finely-divided state, are actually pyrophoric, and take fire spontaneously when only brought in contact with the oxygen of the air.

Correctly speaking, we ought to say, the sulphate of the oxide of copper, or the sulphate of the oxide of tin; but for the sake of brevity it is usual to speak of them as the sulphate of copper and the sulphate of tin. The subject of acids, and bases, and salts is too elaborate a theme to attempt here, and is better studied in the complete work of Auguste Laurient, translated by Dr. Odling, and published by the Cavendish Society; and it is only by reading such a work that we can form an idea of the difficulties in the way of chemical classification. As the animal, vegetable, and mineral substances pass by insensible grada-

tions one into the other, so we may readily understand that the like principle may prevail amongst the non-metallic and metallic elements, and through them into the myriads of organic and inorganic non-metallic or metallic compounds.

Fig. 103. Inlaid Vessels and Work in Gold and Silver Filigree from India; being examples of the great ductility and admirable mechanical qualities of these two noble metals.

Fig. 104. One of the largest Gold Nuggets yet discovered. From a model in the possession of Professor Tennant.

CHAPTER IV.

GOLD. ⊙

The circle amongst the ancient Egyptians was the symbol of divinity and perfection.

Some years ago the author remembers being invited by a large trader in Liverpool to come to his office for the purpose of talking over the sudden influx of gold from Australia, and its probable effect upon the value of the precious metal at home; for such was the general astonishment at the enormous yield of gold, that many serious thinkers believed that the reign of the sovereign Mammon was over, and that we must return to the patriarchal possession of land and flocks of sheep, and herds of cattle, as the only representatives of wealth. The expected crisis of cheap gold is over, and although 17,023,413 ounces of gold, value 64,122,360*l.* sterling, have been exported between May, 1851, and December, 1857, from the two colonies of Victoria and New South Wales, the expected glut and superabundance of gold coinage has not yet been experienced in the United Kingdom.

Considering that the Peruvians decorated themselves with the gold found in their country, and thus excited the cupidity of the cruel Spaniards, it is remarkable that no gold ornaments should ever have been alluded to by travellers as worn by the aborigines of the Australian colonies. The Peruvians certainly appear to have enjoyed a much higher grade of civilization than the poor miserable savages of Australia, and as they erected temples, and were an organized nation under the government of a king, they would naturally make use of whatever metallic substances happened to be present in their country. Unfortunately, their metal happened to be gold, which not only brought

about the destruction of the ancient kingdom of Peru, but sowed the seeds of avarice and sloth amongst their conquerors, which ultimately reduced Spain from a first- to a second-class position amongst nations.

It would not be difficult to attempt an analogy between the Great Britain of the present day and Spain of the ancient time. The latter had their rich argosies and the most powerful fleet in the world; the former now possesses those great gifts of Fortune, and is the envy of the civilized nations. Spain yielded to the luxury and sloth of riches. England is slightly inclining that way, but her good genius prevails, and she is still the most industrious, toiling nation on the face of the earth. Long may Providence decree this state of things! until the colonies England has founded on the other side of the globe become great and mighty nations, and reciprocate with filial love the good they have received from the parent State.

It is truly marvellous that the actual discovery of the treasure should be deferred till the present moment, in spite of the previous tenancy of many of the gold-bearing districts by the aborigines and parties of convicts with their officers. Officers in charge of parties of convicts were located near the present gold-yielding districts, but nothing of the kind was heard or talked of during their weary sojourn there, and a pang of regret must shoot through the minds of those who had the opportunity and the will to *take*, but not the knowledge or powers of observation to *find* the king of metals when they read the marvellous tales of Australian riches. Hardened outcasts, wretched conscience-stricken felons, were neither the men to plan or carry out discoveries; the highest enjoyment they could hope for was the occasional temporary insensibility obtainable from fiery rum. Their food was frequently deficient, and "I have known," said a liberated convict, "a man commit a murder for a meal. I would myself have committed *three* murders for a *meal*." The men who had chiefly sinned to procure gold were marked, as it were, by being transported to a country where gold was given away by Dame Nature, but the fact was hidden from their eyes, and if known at the time, might have caused crimes too dreadful even to think of: every man's hand would have been raised against the other, insatiable avarice would have caused them to spill each other's blood like water, whilst the peaceful colonists would have been outnumbered and destroyed.

In the year 1792 there were only sixty-seven *free* settlers in New South Wales; at the present time, in Sydney alone, there are 310,000 souls; 1100 vessels entered the ports of New South Wales during the year 1857, and these ships were manned by 18,728 sailors. The province of Victoria in 1858 contained nearly half a million of human beings. Surely the "good time" so long expected has come at last, and there is now an escape for the poor and industrious mechanic, who may emigrate to Australia and obtain for himself and family both work and pay. It may be presumed that everybody knows that the colonies of Australia are founded on an island in the South Pacific Ocean, formerly distinguished only by the general title of "New Holland;" a title which has

almost (at least in the minds of the public) merged into and been lost sight of in the glories of Sydney, Victoria, and Melbourne, and spoken of collectively as Australia.

These colonies are about 16,000 miles away from the sound of Bow bells, and whilst gold has been found in enormous quantities, and may be called the staple of New South Wales and the independent province of Victoria, South Australia is the agricultural colony of Australia, and exchanges corn and flour for gold dust, although its Burra Burra copper mines almost equal the gold discoveries in value, as it is said there are "Hundreds of miles in the northern district which abound in copper of great purity." The settled districts now occupy as large a space on the globe as Great Britain, Ireland, and France; and, of the whole continent of Australia, not more than one-fourth is as yet known.

Western Australia is likely to become the great wool- and tallow-producing portion of this highly-favoured part of the globe.

Having thus briefly alluded to Australia, it must be remembered that this is not the only gold-producing country. Our worthy cousins, the Americans, possess California. At the Exhibition of 1851 their gold services of pure Californian gold were examined with loving eyes by the multitude who thronged to that palace. A year before the discoveries of the riches of California—viz., in 1846—Sir Roderick Murchison, in speaking of the gold found in the Ural Mountains in Russia, strongly urged the unemployed Cornish miners to emigrate to New South Wales, and dig and delve in the *débris* and drift of what he termed the Australian Cordilleras; but the lecture-room was 16,000 miles away from the supposed riches, and the vision of wealth might melt away, like the ghost, into "Air, thin air," when the miner reached the end of his long journey; so nobody troubled their heads with what the great geologist had recommended until 1851, when the startling and agreeable news arrived from Melbourne, and then a tumultuous rush from the mother country took place, and the miners no longer wanted to be advised, but prayed to go.

Gold has not only been found in Australia, California, and the Ural Mountains in Russia, but likewise in other parts of Europe. Jamieson states that, "In the time of Queen Elizabeth, extensive workings were carried on in the district of Leadhills, in Lanarkshire, for the purpose of collecting gold; and it is reported that 300 men were employed in searching for it, and that in the course of a few summers a quantity was collected equal in value to 100,000*l*." It also occurs in Glen Turret in Perthshire, in stream works in Cornwall, and in a ferruginous sand near Arklow, in the county of Wicklow, in Ireland, where a mass weighing twenty-two ounces, said to be the largest piece hitherto met with in Europe, was found. The sand of any river is worth washing for the gold it contains, if it will yield twenty-four grains in a hundredweight: and provided always that labour is cheap. The sand of the African rivers often yields sixty-three grains of gold dust in not more than five pounds weight.

Mr. Evan Hopkins, in speaking from experience, "On the superficial

appearance of gold producing grounds in Australia," remarks that "Barrenness, stunted vegetation, broken ridges, and continuous hills of quartz, clay slate, and ferruginous gravel are the chief characteristics of gold-bearing rocks. The surface of such formations is not only not available for extensive agricultural operations, but somewhat meagre for pastoral purposes, owing to the absence of lime in the felspar and the excess of iron and silica, excepting in the soils of the neighbouring valleys. The surface of the non-metallic sedimentary rocks, like those in the neighbourhood of Melbourne, Geelong, and the western districts near the southern coast, presents a very different aspect. The primary elements in these parts of the colony have been more or less dissolved, and deposited in homogeneous layers in a fit state to nourish the vegetable productions, and are very different to the coarse ferruginous gravels of the gold fields. We must be, therefore, very cautious in estimating the value of the whole surface of the higher parts of the primary rocks for agricultural purposes. *The thickness and quality of the soil, generally speaking, varies inversely as the richness of the ground is for metals (in situ)*, therefore they are seldom found equally productive. I have stated that the greater portion of Victoria appears to be more or less auriferous from the Grampians to the Alps, and uncovered by sedimentary rocks (except in some parts of the flanks), very easily examined, not merely superficially, but geologically, and it would be for the interest of the colony to get a survey made as early as possible. This would be the means of removing many uncertainties, and lead to the early development of the actual resources of the country and improvement in inland communication."

The sand of the Danube, Rhine, Rhone, Tagus, and many other European rivers afford gold, and have been at different periods worked for this metal. The only considerable gold mines of Europe are those of Hungary.

Sir John Pettus, who wrote an excellent work on "Metals," date 1686, says "Gold washers who go abroad in the country for gold washings, and get their livelihood by it, they have for the *gold works* a special proving, whereby they do observe how much gold they wash in one day, and accordingly make their accounts, whether the work will bear the charge of washing, and whether it be *poor* or *rich*. If, upon search, he doth find by such proofs that the wash work will recompense his labour, pains, and charges, then each one, according as he is best instructed, doth work the same and make his profit thereby, among whom there are some who do wash that which doth lye in the fields under the mixed earth, as also the sand out of the *flowing Rivers* or channels, and do wash it over a *board*, in which are cut little *gutters* and *wrinkles*, here and there, into which the heavy *gold* will descend and remaineth, but part of it will wash over, especially if the work be rich, and hath *grain gold*.

"Some years past (and this shows how ancient the process of gold washing must be) there was found upon such work and sand by the water-side, a special wash work by which in one day near three hundredweight of rubbish have been washed away, and the gold saved, which is done thus.

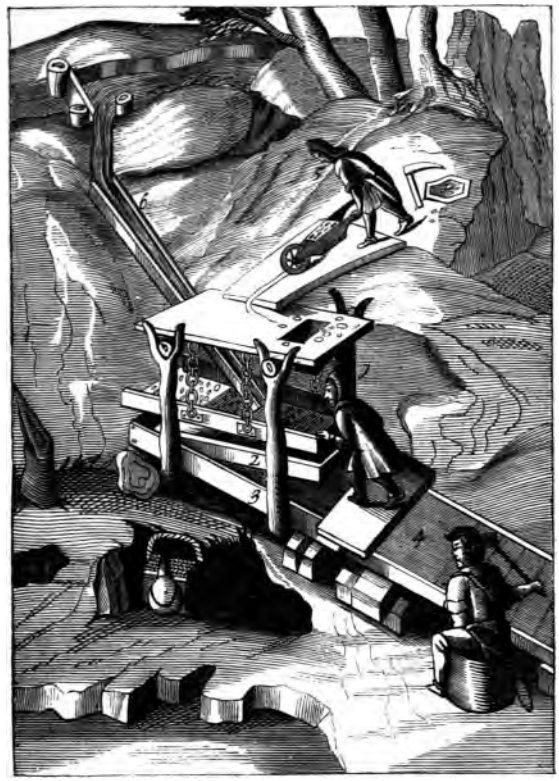


Fig. 105. Ancient Gold Washers (Pettus). "1. The man that worketh with the Rattar (or shaking sieve). 2. The middle floor, whereon that which goeth through the Rattar doth fall. 3. The lower floor, whereon that which cometh from the middle floor doth fall. 4. The *plain receiver*, called the hearth, of that which falls from both. 5. The person that stands on a board, and out of a wheelbarrow throws the matter or oar into the tunnel which guides it into the Rattar. 6. The channel in which water doth run into the Rattar."

"Then some of the gold washers use upon their hearths the strong Timode black and russet *woollen cloth*, over which they do drive their works, because the woollen cloth is rough and hairy, so that the small and round *grains* of *gold* will remain and not run forth (as it will from the Timode), whereby the gold upon the black cloth may apparently be known, though it may be small and little. Others use, instead of the Timode, a black woollen cloath *Linsey woolsey* (half linnen and half woollen,

wrought in the manner as the Timode is), upon which the gold doth stick better, and such cloths do last longer, because of the *Linnen* that is among the *Woollen*, which doth strengthen it, therefore it is better for this work.

"But there is another way of washing (not much in use), which is called Driving and Washing through the long Rattar; but according to my mind it is not so convenient a way for the small works, which have great and small gold, and are both sand and clay together, yet I do not much decline from the before-described Rattar work. For in this labour or washing, because of the turning in the upper and lower falls, the running gold is preserved better and the gold goeth with the small common work over the plain hearth upon which it is driven, and the manner of doing it is seen in the following sculpture."

The classical story of Jason and the Golden Fleece has been frequently suggested to be a fanciful romance, in which is embodied a rude mode of collecting gold (washed down with the stream), by means of sheep's fleeces. The fleecing of the King of Colchis probably meant the robbery of the gold he collected in this way from the streams and rivers of his country. The Pactolus, a small river in Lydia, formerly afforded so much gold that it is alleged to have been one of the chief sources of the riches of Crœsus.

The presence of gold in Europe has already been alluded to. There are few considerable mines of gold worked in Asia; Siberia and Beresof afford it; likewise the numerous islands in the Indian Ocean, as Java, Japan, Formosa, Borneo, and the Philippines. In Sumatra many thousand ounces of gold are collected annually. Africa has long been celebrated as the land of gold dust, and it is supposed that Ophir, from which Solomon obtained gold, was a country on the coast of Africa.

America is considered the richest country of the world in gold, and not only includes Mexico, but California also, the kingdom of Granada in South America, the Brazils, and other localities. Since the discoveries of California and Australia, the public mind has become accustomed to hear of pounds and hundredweights of gold, and although the produce of this precious metal at the present time most likely transcends that of all other times, it must be remembered that King Solomon received 666 talents of gold (being more than 27 tons weight) in one year; "and all King Solomon's drinking vessels were of gold, and all the vessels of the forest of Lebanon were of pure gold; none were of silver; it was nothing accounted of in the days of Solomon." (1 Kings, x. 21.) Diodorus says, that the tomb of King Simandius was environed with a circle of gold 350 cubits about, and a foot and a half thick, and estimating the Roman cubit to be 17·4 inches, it would be easy to calculate the enormous value of this mass of gold. Semiramis erected in Babylon three statues of gold, one of which was 40 feet high and weighed a thousand Babylonian talents. For these statues there was a table or altar of gold 40 feet long and 12 feet broad, weighing 50 talents.

We have now to ask, in the first place, what are the peculiar characteristics of the rocks likely to afford gold?

Secondly—Having procured a stone or mineral that looks like gold, how is it possible to determine whether it is the precious metal or not?

For the ability to answer the first question, we take our information from nature; because, at greater or less depths, we perceive that the crust of the globe is not mere loose earth, but is formed of various layers, or what geologists call strata (from the Latin *stratum*, a bed). These layers, strata, or beds, whether hard or soft, are termed collectively rocks, which admit of a very simple division into stratified and unstratified rocks.

The stratified have all been deposited from water. Hence they are sometimes called aqueous rocks.

The unstratified, it is supposed, have been once melted by some fervent heat; they have been molten and liquefied like glass in the furnace. Their other name is consequently igneous (*ignis* being the Latin for fire).

The stratified rocks consist chiefly of three kinds of earthy matter—viz., sand, clay, and lime. The sandy rocks are gritstone, sandstone, sand, gravel, pudding-stone or conglomerate; the clayey rocks are clay, clunch, marl, shale, and slate; and the lime rocks are marble, limestone, chalk. If good examples be wanting of the application of stratified rocks in London, we may point to the Marble Arch, at one of the entrances of Hyde Park, or the buildings faced with Portland stone, or the New Houses of Parliament. Unstratified or igneous rocks are lava, basalt, greenstone, and granite, consisting of quartz, felspar, and mica.

Familiar illustrations can be given of the application of unstratified rocks by reference to Waterloo Bridge, composed of granite, or to the magnificent vases of Swedish porphyry exhibited in the Hyde Park Palace, or the basalt columns of the Giant's Causeway.

The first, viz., the stratified, are deposited in regular order, like the stones of a mason who erects a column: as the pillar must have a beginning with the foundation, so with the strata. Common sense will perceive that the lowest are the first laid down, then a second, followed by a third. Thus we have the grand division of stratified rocks into primary, secondary, tertiary, or, in plainer language, into first, seconds, and thirds, which are again divided into systems and formations. It is not, of course, supposed that the rocks are to be discovered in regular sequence and in unbroken layers over the whole globe; but it is satisfactorily determined that, though the strata are broken or displaced, like the ruins of an ancient building, the succession can never be inverted. The foundations of an ancient structure are traced out, and even the exact position of the inscribed cylinders of Nebuchadnezzar, deposited two thousand two hundred years ago, can be pointed out by a Sir H. Rawlinson, whilst the pillars and upper portions of the temple may be in fragments; in fine, the learned observer and student of ancient buildings never mistakes the upper part of the structure for the lower one, and so it is with the geological succession. A great number of examples might be adduced where palæozoic rocks or primary deposits, instead of being in

their proper places, "full fathom deep," are the topmost strata, and stand out on our coasts battling with the winds and waves.

There is a fine example of this nature in the famous "Marsden Rocks," easily reached from Newcastle by the South Shields line. Several rooms have been excavated in this rock, and many romantic associations are connected with it. The mass consists of a succession

Fig. 106. The Marsden Rocks.

of layers of magnesian limestone. Beneath this rock should repose the speciality of that locality—viz., coal, the "black stones" that Pope Pius II., in his description of Europe, written about the middle of the fifteenth century, says he beheld with wonder, given, in Scotland, as alms to the poor. The carboniferous order being consolidated, another period, to which no limit can be assigned, seems to have elapsed; after which, violent disturbing causes, grinding down the chain of mountain limestone to the west, deposited above the coal measures, in successive layers, the material of the magnesian limestone. The whole region traversed by this limestone appears to have been afterwards ravaged by denuding torrents from the same direction.

The most striking peculiarity of the Marsden Rock is the large and well-cut bridge which the restless waves have channeled through it.

Magnesian limestone belongs to the palæozoic or primary rocks, and yet it occurs at the surface of the earth.

These simple facts in geology would not have been mentioned, except

to answer a question likely to arise in the unscientific, though otherwise clever mind—How can geologists say which are the oldest rocks? or, What do they mean by primaries, secondaries, and palæozoics?* &c. &c.

The simple classification already mentioned established in the mind, it is easy to comprehend that, if Nature be true to herself, she cannot invert or turn in a contrary direction this arrangement of the stratified rocks. The primary being first deposited, cannot be found above the secondary, or the tertiary under the secondary. Pictures in a book help to instruct both young and old; an imitation of nature, by way of experiment, however rude, may assist us. Place in a glass jar strips of white, blue, and yellow calico, each with strings attached to one end, which carry up and lay over the edge of the glass; cover these with three layers of seeds—at the bottom rice, then black horsebeans, lastly haricot beans. Here we have primary, secondary, tertiary. Beneath and outside the jar arrange a bit of red calico, which may be called the igneous rocks. Here is a mechanical illustration of the previous facts stated; but how are we to know (in nature) primary from secondary, or the latter from tertiary?—By the remains of animals, fishes, plants, and shells, called fossils, deposited by nature with the strata, like the bottle holding the coins placed under the foundation-stone of many "a goodly pile" in the present generation.

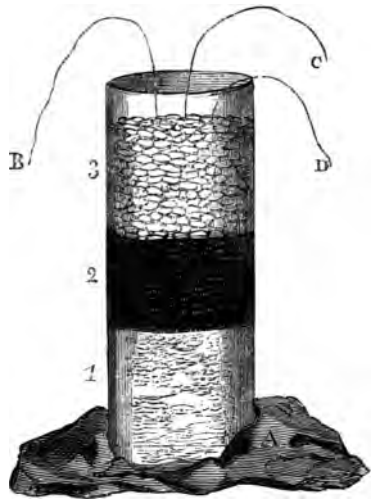


Fig. 107. Glass Jar standing on a piece of red calico, A, and containing the three strips of calico covered with the layers of seeds. 1. Rice. 2. Black horsebeans. 3. Haricot beans. B. String attached to the white calico at the hollow of the jar. C. String attached to the blue. D. String attached to the yellow.

Fossils are well termed "the medals of creation;" and the gold seeker would not experience much difficulty in appreciating the fossil remains of a peculiar fish, now extinct, of the lobster tribe, called, in scientific language, crustaceous, and known to naturalists as the Trilobite, having a jointed body ploughed with two long furrows, and thus divided in the length into three parts (hence the derivation of trilobite, from the Greek

* Palæozoic means characterized by ancient animals.

treis, three; *lobos*, a lobe). Now, this and other very marked fossils belonging to the older palæozoic rocks, have been stated to be associated with the precious metal; and gold, like coal, has natural companions, which enable the geologist to pronounce with almost perfect certainty that it may or may not be found in certain localities.

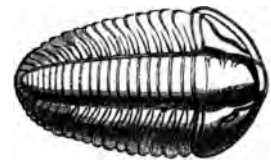


Fig. 108. Fossil. The Trilobite.

Our thirst for knowledge will suggest other pertinent questions—Had not gold a beginning? or, How is it supposed to have been formed in the bowels of the earth?

Here we shall allude again to the illustration of the jar and the seeds, Fig. 107, in explanation of the facts, the more particularly as Mr. Stuchbery, in his Government report, states "that most of the hills west of the principal gold diggings are capped with basalt," and basalt is an igneous or unstratified rock. "I find by observation that the trappean rocks, such as basalt and porphyry, have arisen to the surface, projecting themselves through the schistose rocks, and by overflowing and after degradation, they give origin to most of the round-topped hills." Here, again, we find igneous rocks in the neighbourhood of gold; and Mr. Stuchbery also observes that quartz must be regarded as the chief matrix or womb of gold.

If igneous rocks were below the unstratified originally, why do they cap hills at the present time? Here speculation must assist us. It has been assumed, that after the stratified rocks were deposited, certain convulsions of nature (which occur even at the present time in the shape of earthquakes and fiery volcanoes, like those of Etna or Mount Vesuvius) took place, by which the melted rocks were actually protruded upwards; just as the piece of white calico may be pulled from the bottom of the seeds in the jar, causing the strata to bend upwards. Let that rude imitation represent the melted rock, such as granite or basalt, pushed through the other strata. During this grand operation of nature, the surrounding strata must crack and leave fissures. Into these places the melted rock might continue to run; then another interval of time would elapse—the rocks previously in a state of fusion cool and contract, leaving other cracks and fissures. In these places or hollows the metals and minerals are supposed to have been deposited, perhaps by the same electrical agency through which we obtain a perfect copy of any medal or cast, by the process of electrotyping. Natural currents of electricity may have gradually produced the veins of minerals, and thus originated gold in common with other native metals, found generally associated with quartz, which latter appears to have been more plentifully deposited than any other mineral substance. Quartz is only another form of sand, and is an oxide of silicium. Let us, then, pull up a piece of blue calico from the bottom of the seeds, by the side of the white, to represent quartz, and also another strip dyed yellow, to represent the gold, and we have done practically all that can be effected with this

simple arrangement to give a mechanical notion of the origin of gold. We have, finally, to imagine the top of the seeds, through which the different coloured calicoes are protruding, and which we have called igneous rock, quartz, and gold, to be washed by water, and carried off miles away from the original source. Thus it is supposed that the rocks containing gold have been subjected to the action of breakers and waves, like our sea-coasts at the present time. These waves, gradually receding or advancing, have carried off large lumps of the rocks, and, by rubbing, reduced them to smaller particles. Hence we read of gold in the dry diggings being found in drift, which is nothing more than particles of rocks transported from their original position. In unison with these observations, we may again quote Mr. Stuchbery:—

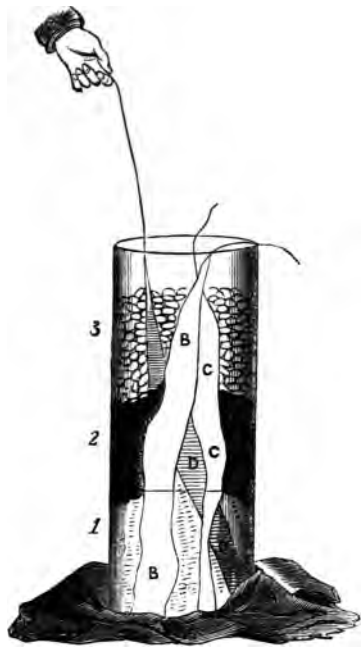


Fig. 109. Glass Jar, same as at Fig. 107. B B. White calico, pulled up through the three layers of seeds. C C. Blue ditto. D D. Very thin strip of yellow calico, to represent the gold. A. Red calico, on which the jar stands.

"Nor is it at all surprising that gold should be so rarely found in its original gangue or matrix, as compared with the large quantity found in the limited areas of the earth's surface, if the mind is only prepared to grasp the immense amount of disintegration (*i.e.*, separation into smaller parts) and consequent denudation (washing away so as to lay bare the inferior strata), together with the lapse of countless ages which may have taken place since the removal of the first atom to the present time. As a proof of the transporting forces I may mention, that in the bed of the Summerhill Creek I found rounded blocks of fossiliferous limestone, which I am convinced must have come from the mountain range between Summerhill and Emu Swamp, thus traversing the tortuous course of the creeks, passing over precipitous falls through deeply-hollowed holes, and other impediments; and yet large portions of this limestone still remain as evidence of the power of these periodical mountain torrents. This single instance is sufficient to explain the abraded, battered, and water-worn character of the gold, and the general

absence of any particle of its original investing but more fragile matrix.

"In Europe gold occurs in igneous and metamorphic rocks, such as granite at Gastin in Salzburg, gneiss in Upper Hungary, and mica slate in Salzburg and Tyrol; in clay porphyry in Transylvania; in hornblende rock, along with auriferous iron pyrites; in veins of quartz at Edelfus, in Sweden.

"In Asia gold occurs in Siberia in veins that traverse hornblende rock; it is also obtained from veins, where it is associated with quartz or from alluvial soil, when it occurs in the form of dust or in masses;" also in the sand of rivers. "In Africa gold is found in the sand of rivers or the alluvial soils of valleys or plains, and at the foot of those mountain ranges in which are situated the sources of the rivers Gambia, Senegal, and Niger."

In America the gold is chiefly collected in alluvial soil in the beds of rivers, and also from veins. Jamieson, who wrote his work in 1816, says, "On the coast of California there is a place of fourteen leagues in extent covered with an alluvial deposit in which lumps of gold are dispersed." How strange! that above thirty years should be permitted to elapse before the great discoveries of gold were made in this part of the world!

For the sake of greater simplicity, nothing has yet been said respecting the metamorphic or transformed rocks, such as green and chiastolite slate, mica and hornblende schists, porphyry; but it must be evident that, if great eruptions of melted and red-hot granite, &c., have taken place from below, they could not pass through stratified rocks without affecting them to a certain degree, or changing their physical aspects so as to make them assume the appearance of igneous rocks. Any of the stratified rocks may be changed to metamorphic ones; but as the primaries are the lowest and nearest to the granite, so the metamorphic rocks are usually primary rocks, and in a geological chart, such as that of Mr. John Morris, are placed at the bottom of the palæozoic or primary, being termed hypozoic or metamorphic rocks.

We have spoken of strata, but not yet afforded the precise clue which is to guide the gold seeker in his geological opinion of the rocks and the probable existence of gold in any range of country under examination.

The following plan, however, may be recommended, founded on a statement made by Professor Forbes, that "it is useless to waste time in searching for gold in the older tertiaries, or in secondary rocks, so far as Australia is concerned; though none of the latter appearing to be as yet discovered in Australia, the gold seeker is not likely to go wrong through them. The *older* palæozoic, the metamorphic rocks that lie beneath them, and the *newest* tertiaries, all taken in connexion with mountain chains, are the best guides in this matter."

The author recommends that every emigrant who intends to seek for gold should purchase a small collection, specially and chiefly arranged by Mr. Tennant, the eminent mineralogist of the Strand.

The collection may consist of two small deal trays, one containing fossils of the most decided and ordinary character, belonging to the older tertiaries and secondary rocks, which are NOT associated with gold.

The other to contain specimens of the older palæozoic fossils, metamorphic rocks, newest tertiary fossils, with a specimen or two of an igneous rock; all of which are said to be characteristic of the presence of gold.

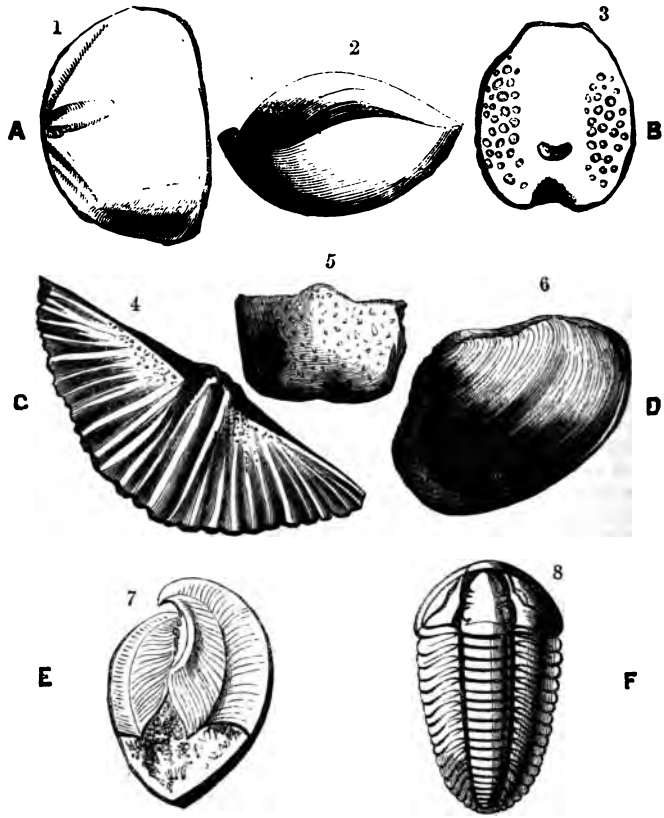


Fig. 110. A to B. Australian Fossils of the older Tertiaries. 1. Echinolampas. 2. Spatangus. 3. Terebratula Compta. — C to D. Australian Fossils of the Upper Palæozoic or Silurian Rocks. 4. Spirifer. 5. Productus. 6. Pachydomus.—E to F. Lower, or older Palæozoic Fossils. 7. Pentamerus. 8. The Trilobite.

At the famous Ballarat diggings, the following strata are passed through to reach the celebrated blue clay (one of the newest tertiaries) which was found to be so rich in gold.

1. Red ferruginous earth and gravel.
2. Streaked yellowish and red clay.
3. Quartz gravels of moderate size.
4. Large quartz pebbles and boulders; masses of ironstone set in very compact clay, hard to work.
5. Blue and white clay.
6. Pipe clay.

With a collection of specimens to look at on the voyage, and a month's practical geologizing at the diggings (*i.e.*, familiarizing the eye with the earthy companions of gold), the intelligent though ignorant emigrant may bid defiance to hard geological names, and lead the way, perhaps, to fresh diggings, thus reaping the first and best harvest of gold in a new district: as it is evident he does not require a knowledge of geology to guide him in digging a hole close by the side of others who are actually finding the precious metal.

Geology is of incalculable value to that man who will venture *to lead* a party away from the multitude and search for gold in unexplored districts.

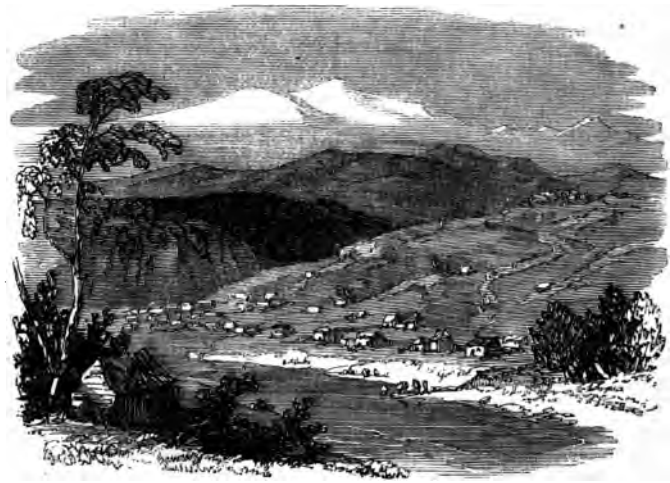


Fig. 111. Australian Gold Diggings.

Having spoken at p. 177 of the eruption of melted rocks, it is right to bear in mind that many intelligent geologists ignore altogether the action of fire, and maintain that the gold was entirely deposited by electro-chemical decomposition. Mr. Evan Hopkins is one of the most

determined opponents of the red-hot theories, and he remarks, in his pamphlet on "The Geology of the Gold-bearing Rocks of the World," "When persons see the large masses of gold obtained from the surface of the quartz, or the edges of the primary slates, they are too apt to think that such productions are caused by melting or intense heat." Such ideas, Mr. Hopkins says, are incorrect, and from the circumstance of the metal being marked with the most minute striæ of the quartz, which contains the usual proportion of water, he maintains "that this is a state of things totally inconsistent with an intense melting action, but identical to that resulting from a battery and an aqueous solution."

In the second division of the subject, the most important question remains to be answered: "Having obtained a substance which looks like gold, how are we to be sure that it is or is not the precious metal?"

Before treating of the chemistry connected with this part of the subject, it may be premised that the explorations conducted in the general drift are termed "dry diggings;" the search after gold in the bed of a river is called a "wet digging;" whilst the operations conducted by the assistance of machinery in which the quartz containing the gold is crushed, washed, and amalgamated with quicksilver, may be distinguished from the others as quartz-crushing and mining.

The latter plan is now coming steadily into use, although it requires expensive machinery, a number of hands, and, of course, large capital, and is a process better worked by a company or association of monied men. Quartz-crushing is now proved to be very profitable, and a friend of the author, just returned from Sydney, informed him that he knew a party of six speculators who had a large tract of ground assigned by a creek in Australia, where they had erected a 12-horse power steam-engine, with proper machinery for crushing quartz and the amalgamation process. This speculation yielded at first 2400*l.* worth of gold per week, but it has since diminished. They employed thirty men, and gave wages from 5*l.* to 30*s.* per week, besides the necessary rations.

The Melbourne correspondent of the *Times* of May, 1859, speaking of quartz-crushing, remarks that "The application of capital and costly machinery to the production of gold, especially to quartz-mining, is rapidly increasing, and some very rich quartz reefs have been lately opened. At the Reedy Creek, about twenty miles from Kilmore, and about fifty from Melbourne, in a rough, hilly country, quartz reefs of a very rich character abound.

"In some cases the yield has been as high as thirty-one ounces of gold to the ton of quartz. In some specimens that I have seen the gold was so minutely distributed through the quartz as to be only here and there visible, yet the weight of the specimens betrayed their richness, and they yielded sixteen ounces to the ton. Last month the paper noticed a lump of amalgamated gold, weighing 730 ounces, as the largest yet produced; but since then a lump of 1320 ounces has been obtained from one crushing. It was procured from forty-five tons of

quartz taken from Iron Bank Gully, at Bendigo. The labouring diggers now perceive that the old mode of independent digging must in time wear out, and in many cases they are becoming reconciled to working for wages."

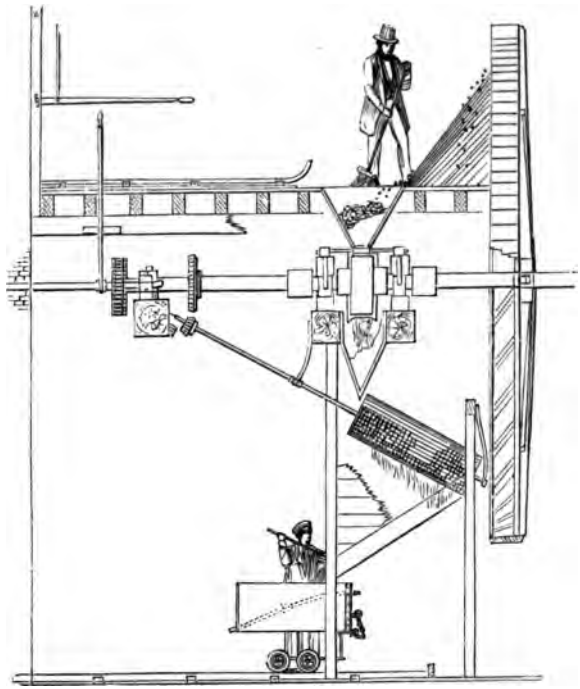


Fig. 112. A Cornish Crushing Machine worked by a Steam Engine.

The dry diggings are the most generally worked, because nature has done the work of the steam-engine by crushing and breaking up the original matrix, and spreading the gold over a large range of country; we cannot, therefore, fail to notice machines mentioned in nearly all letters from emigrants, called "cradles," used extensively to rake or *wake* up the gold, in contradistinction to the usual office of this machine, when it contains a living occupant, who is supposed to be sent to sleep with greater facility by its use.

No doubt the original idea of cradles was taken from Nature, as a hollow tree, cut down and divided in halves, with a few rude

partitions, or ribs, at the bottom, would answer the purpose of the gold-washer.

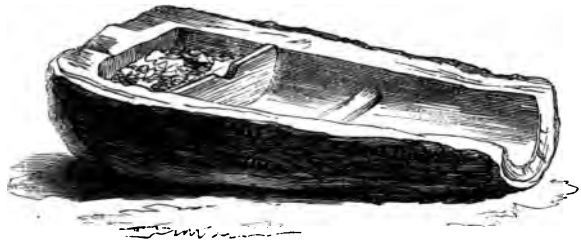


Fig. 113. Rude Washing Cradle, consisting of the Half of the Trunk of a Hollow Tree.

A little experience only is required to work them properly. Thus the earth is thrown into the upper sieve with plenty of water; here the large stones are retained, which are carefully looked over for gold; then the cradle is kept continually rocked, the motion being graduated and not too violent; the continual shaking and flowing of the water washes away the earthy matter, whilst the gold, which is more than seven times heavier than anything likely to be associated with it, sinks to the bottom, being retained by the cleets or ribs of wood put across the lower part of the machine.

Professor Hunt remarks that Herodotus informs us that the people living near the sources of the Indus obtained a large quantity of gold from the eastern border of the great Bactriana and the desert steppes of Cobi. Much was obtained by washing sands, and more by digging; and both Herodotus and Pliny tell us a strange story of gold being turned up by enormous ants—"not so large as a dog, but bigger than a fox," and that from these ant-hills the Indians obtained the greatest quantity which they supplied to the monarchs of Persia. Humboldt has shown that this story arises from the double meaning of a word. Herodotus again tells us that "in the north there is a prodigious quantity of gold, but how it is produced I am not able to tell you certainly. It is affirmed, indeed, that the Arimaspi, a people who have but one eye, take the gold away by violence from the griffins;" but, says the father of history, "I can never persuade myself that there are any men who, having but one eye, enjoy in all other respects the nature and qualities of other human beings.

More complicated cradles and machines were made at the time of the first rush to the "Australian diggings." The cradles had perhaps one recommendation—viz., that they could be used as clothes-boxes by the emigrants on board ship, and would serve as models for others; and in the next cut we give pictures of some of them, the principle upon which they acted being that of agitating the auriferous earth with water,

the settlement of the heavy gold to the bottom of the cradle or machine, whilst the lighter earth was washed away.

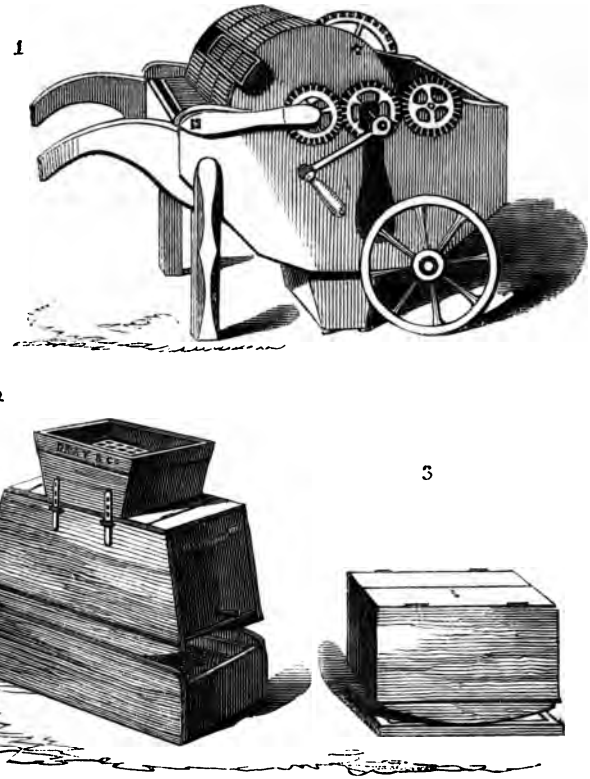


Fig. 114. No. 1. Barnes' Barrow Gold-washing Machine. No. 2. Dray's Gold-washing Machine. No. 3. Hill's Gold-washing and Reserving Machine.

Mr. Jukes, speaking of cradles, makes a very appropriate comparison between them and the beds of rivers. He says, "Rivers are indeed 'great natural cradles;' sweeping off the lighter and finer particles at once, the heavier ones either sticking against natural impediments or being left wherever the current slackens its force or velocity. A cradle is a wooden trough with several 'cleets,' or ribs, fastened across its bottom. Into the head of it is placed a quantity of auriferous sand or gravel, water is poured over it, and motion communicated by rocking

and tilting the cradle. The running water carries off all the lighter matters, and leaves the heavy stones and lumps of gold, either in the head of the cradle or accumulated at its bottom against the 'cleets,' fastened across to arrest them. Turning the bed of a river, then, wherever such a manœuvre is practicable, is like a miner examining the bottom of his cradle; and if it happens to be done at the right spot where there are several natural 'cleets,' or bars, or where there are holes in the rock for the gold to drop into, it is likely to be rewarded very richly by the accumulated result of centuries of natural gold washings.

"In gold mining vast quantities of hard rock have to be quarried and removed to be crushed by powerful machinery, and to be washed over and over again, or to be treated by other expensive processes; while in gold washing, or separating gold from drift, all the mining and the crushing, and a good part of the washing and sorting of materials have been already done for the miner by nature."

A very good machine made by Mr. Barnes consists of a stout cylindrical vessel of galvanized iron; in the centre is placed a strong shaft, with iron arms attached; the whole being worked by a set of cogs and power-wheel. The earth is thrown into the top (where the large stones are retained by a sieve), with plenty of water; the iron arms are worked round and round, just as we see in a brick-field the clay and other materials worked up in a tub with horse-power. At regular intervals from the top are placed little doors with screws, and as the washing proceeds, the person engaged in using it opens first the top one, permitting a little of the earth and water to flow into a pan, which he carefully examines for gold spangles or dust; if no glittering particles are apparent (and a large magnifying-glass would greatly facilitate the examination), he passes to the second hole, from that to the third, thus tracing the gradual descent of the gold, until he arrives at the bottom of the vessel; here a plate or slide is withdrawn, and the gold dust, with some earthy matters, falls into the pan. After two or three iron buckets of the earth, rich in gold, have been collected, the contents are washed over again in the machine; and it is stated that by this apparatus one ton of earth (whether sand, clay, or gravel) can be washed per diem with the assistance of two boys of twelve years of age, or one able-bodied man.

When the first rush took place to the diggings, men worked singly or in couples, but the lawlessness and utter recklessness of such a mixed society soon caused the industrious and peaceful to band together for the protection of life and property. Parties of six were the usual number of the joint-stock company, because six were less likely to quarrel than eight or twelve, and also because they were the smallest force that could work together. Two of the band worked together, one in the hole or claim, and the other at the pit's mouth; two guarded the tent and two slept; those who slept always retired with their revolvers ready at hand to use immediately on the slightest alarm being given. The author was told an authentic story where six men had banded together as described; but, in consequence of extra work, the

watching was not complete, one watcher being allowed to sleep whilst the other tried to keep his eyes open, and singly to guard the united property. The single watcher had at last yielded to the enticing god; but the other, who had permission to sleep, by some strange fatality, felt uneasy, and having some apprehension of being robbed, could not slumber; suddenly the light, or rather the darkness, from the opening of the small flap in the tent, passed across his eyes, when he immediately cried out, "Who's there?" and receiving an answer, "Oh, I beg your pardon; I've made a mistake," he did not wait for further questioning, but instantly fired his revolver. The whole party being roused, sallied out, and found a man shot and lying dead, whose body they thrust into the open street or lane between the canvas houses; and finding that the corpse was removed before daybreak, surmised that this man belonged to a gang of thieves who risked their lives in this way, with the hope of surprising the toil-worn and sleepy gold-diggers. A friend of the author told him that he was fairly cleaned out three times by thieves, who carried off everything during very temporary absences from his canvas home.

We now pass to the strictly chemical part of the subject, "the discrimination of gold from other metals and minerals."

Our next cut displays a series of mineral specimens, many of which glitter, and look like gold, suggesting, however, the old caution, that "all is not gold that glitters."

There are three specimens, Nos. 1, 2, 3 (Fig. 115), containing only iron pyrites, or sulphuret of iron.

There is another set of three, Nos. 4, 5, 6 (Fig. 115), containing copper pyrites, or sulphuret of copper, and carbonate of copper.

All these have a shining aspect, and are frequently mistaken for gold. But the other three, Nos. 7, 8, 9 (Fig. 115), are very modest-looking specimens. These have come from California and Australia, and contain gold, although any one might consider them, by mere inspection, to be worthless.

In the absence of specimens for comparison, the gold-seeker probably having none, the most simple modes of ascertaining the difference between iron or copper pyrites and gold may now be pointed out.

The only apparatus required is a common anvil and hammer, and a red-hot shovel. A piece of gold may be treated most roughly with the hammer on the anvil: it may be beaten out and extended, thus demonstrating that it has the property of malleability, which gold enjoys in the very highest degree, as this metal may be beaten out into leaves the $\frac{1}{282000}$th of an inch in thickness; *i.e.*, it would take 282,000 to make a pile of gold leaves one inch high. One grain also can be made to cover $56\frac{3}{4}$ square inches. We cannot, then, beat the gold to fragments, but may do so with the pyrites; and directly it is struck with the hammer, sparks of fire are apparent (hence its name, from the Greek, πῦρ, fire, as it was employed formerly for striking a light); at the same moment the mineral is broken to pieces; it is very brittle, and by con-

tinuing the hammering may be reduced to powder. In the next place, the powdered mineral is to be sprinkled on a red-hot shovel, when a blue

Fig. 115. Series of Specimens, from Mr. Tennant's. 1, 2, 3. Specimens of iron pyrites. 4. Malachite. 5, 6. Copper pyrites. 7, 8, 9. Specimens of rock containing gold.

flame is apparent, and by smelling the fumes which rise from it, the odour of burning sulphur is soon detected. It is, perhaps, unnecessary

to remark that gold is incapable of producing any odour or fumes when thrown upon a red-hot iron.

Fig. 116. Testing for Pyrites by the red-hot Shovel.

These are the simplest tests to distinguish the pyrites minerals from gold, and we shall speak of the mode of testing yellow mica in another place: indeed, it may be observed, that there is little danger of the gold-seeker being deceived by Nature, her ways are so unvarying, plain, and simple. The emigrant has most to fear from the chicanery of his fellow-man; and perfect imitations of *gold nuggets* have made their appearance at several of the sea-ports, manufactured in the toy-shop of the world; regular "Brummagem" wares, so well got up as regards weight and outward appearance (for they were electro-gilt), that many have been sold as specimens, and of course their chief destination was the diggings—at least it may be supposed so,—because already some parties sending brass filings from Sydney, under Government escort, and paying duty, have been detected, and their precious wares confiscated, whilst their names have been most liberally treated by Government in the Sydney papers; in fact, they have been deservedly exposed, and lost nearly all their trade in consequence.

How, then, can gilt *brass* filings or sham nuggets be distinguished from the real article?

In the first place, the author recommends every person intending to trade in this gold to take out three pint bottles of acids; viz., one pint of nitric acid, commonly called aquafortis; one pint of hydrochloric, or muriatic acid; one pint of oil of vitriol, or sulphuric acid: these acids will not cost more than eight shillings, bottles and all, and may be pur-

chased of Mr. Thomas, chemist, Pall Mall, London, and their great value will soon be apparent.

If some glittering copper turnings are placed in a test glass, or wine or other convenient glass, and some gold leaf in another, on the addition of aquafortis or nitric acid to both of them, a violent commotion is visible in the glass containing the copper, and orange-red fumes escape, which are very disagreeable to the lungs; but the gold remains perfectly tranquil and undisturbed, and if the nitric acid is pure, they might probably remain in contact with each other for a century without any action on the gold taking place. If a similar experiment is made with hydro-

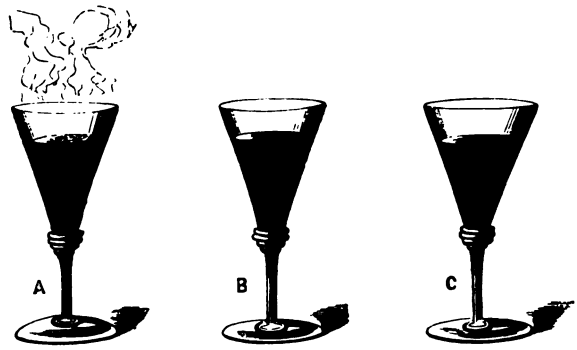


Fig. 117. A. Copper turnings or sham nugget in nitric acid. B. Glass containing gold leaf and nitric acid. C. Glass containing gold leaf and hydrochloric acid. When the contents of B and C are mixed together, the sparkling fragments of gold leaf soon disappear.

chloric or muriatic acid and gold leaf, no solution of the metal takes place, the gold will not dissolve in this acid; but when the contents of the two glasses, viz., the one containing the nitric acid and the other the hydrochloric acid, are mixed, the mixture called *aqua regia* is formed, which quickly dissolves the royal metal gold; and if the glass containing the two is placed on one side, the chlorine of the aqua regia will attack and take the gold into solution, rendering it for the time perfectly invisible. Founded on this principle that gold is only soluble in aqua regia, or other liquids in which chlorine is set free, a simple method of examining rocks (in which the precious metal is not visible) may now be described. In the absence of a flask, ring-stand, and spirit lamp, a more simple method may be employed, which would be better adapted to the wants of those pioneers of civilization who, living in tents in unexplored regions, must take what they can procure and not what they want. The apparatus required will be, a common saucepan, a few "doctor's phials," a bit of tinfoil, or some tin scraped off any tinned iron vessel, a few nails,

and the three acids already named—viz., the aquafortis, the muriatic acid, and the sulphuric acid; these, with an ordinary fire, are all that will be required.

For the purpose of demonstrating the use of these materials, three specimens of rock, one of which is known to contain gold, may be powdered separately either on the anvil by the hammer or with an ordinary pestle and mortar, and a portion of each specimen can be placed into a two-ounce wide-mouthed phial. Into each of the three phials containing the powdered rock may be poured some aqua regia—*i.e.*, two measures of hydrochloric acid and one measure of nitric acid. The bottles and their contents are now ready to be heated; but, before doing so, a bit of tinfoil and some muriatic acid may be placed in another similar phial, also a few iron nails, some water, and a small quantity of oil of vitriol in a fifth and similar phial, so that there are three phials containing the rocks under examination, and two containing the materials required to make the tests for gold.

Fig. 118. The five Phials in the Saucepan containing Water, and placed over the Fire.

The five phials may now be arranged in a saucepan which has a fold of paper or a bit of cotton rag at the bottom to prevent the heat being conducted too quickly to the glass from the bottom of the iron pot. Cold water is now poured in, and the saucepan and its contents placed over an ordinary fire.

As the water becomes hot and boils it communicates the heat slowly to the contents of the phials, which are now placed in what the chemist would term *a water bath*. In about half an hour the saucepan may be removed from the fire, and the five phials will be found quite sound and not cracked by the heat, because they have been very slowly warmed. Three of them will afford the orange-red fumes usually apparent when aqua regia is used, the other two contain colourless liquids, which may still effervesce slightly if a small portion of either the tin or iron remains undissolved, and they are the tests. Pour half the contents of each of the three bottles containing the minerals separately into three tumblers half-full of rain-water or the purest water that can be obtained, distilled water, of course, being the best for the purpose, and then add to each of them a portion of the solution of tinfoil.

The contents of two of the tumblers give no indication of a solid pre-

cipitate, or matter thrown down, because one, we will suppose, was yellow mica (a mineral by-the-bye frequently mistaken for gold), and the other a mixture of quartz and iron pyrites; but the contents of the third tumbler afford a very different appearance, and directly the solution of tinfoil is added, a purplish precipitate, darkening the whole fluid, is perceptible, the perfection of the purple colour being chance work, as the present operation is somewhat rough; but in the hands of the skilled a solution of gold yields a magnificent purple compound; when a solution of the oxides of tin is added to it, the colour is called "*The purple of Cassius*," and is used for imparting the rich ruby colour to glass.

The mode of making this purple will be given in the experiments with gold at the end of this article. In the rough experiment already described perfection of colour cannot be expected, but enough is perceptible to enable the observer to distinguish the rock which contains the gold from the other two minerals that do not contain it. Corroborative testimony, however, is absolutely necessary before the *examiner* would make up his mind as to the presence of gold; and taking the remaining half of the solution supposed to contain the precious metal, it may be poured into a fourth tumbler half-full of distilled water, and to this the solution of the iron nails in water and sulphuric acid should be added. Gradually a marked precipitate or dark matter thrown down or produced becomes visible. Let this settle during the night; the next morning pour off the fluid, a dark brown mud is perceptible; earthy as it looks, this humble mud is *metallic gold*, the standard of excellence, *par excellence* the sinews of war—the handmaid of peace! Collect this mud by pouring it on a piece of paper, place by the fire or in the sun, and let it dry. Then rub the dark particles with a bit of iron or steel (a key for instance); immediately the mud changes its poverty-struck appearance (as by the magician's touch) to the gay and brilliant shining yellow all-commanding gold. The proofs are complete; "the purple of Cassius" is corroborated by the mud raised to brilliant gold, as already explained.

If some of the particles are gently smeared on a stone, such as a "razor hone," they leave a particular-coloured streak. These marks or streaks were anciently employed as one of the chief tests of the quality of gold; and hence the use of the "touchstone," which is even mentioned in the Bible. The stone was not employed alone, but in conjunction with "touch needles," whose exact composition was known and made for special purposes; thus Sir John Pettus minutely describes—

"1. How gold in lumps, plates, ingots, *or coyned* gold is to be assayed, and first of 'touch needles.'

"2. How the *white touch needles* are to be made.

"3. *How* touch needles *are to be made and used for* crown gold.

"4. *The division of the* touch needles *when the metal is* half white *and* half red.

"5. *How* touch needles *are to be made from* Rhenish gold, *in which there is two parts* white *and one part* red."

From the above division it will be seen that considerable trouble and

expense would be incurred by the manufacture of a number of touch needles, hence Pettus remarks:—

"But the *goldsmiths* take not so much pains nor are at large expences, but cut a piece of a *duccate*, and of a *crown*, and of a *Rhenish*

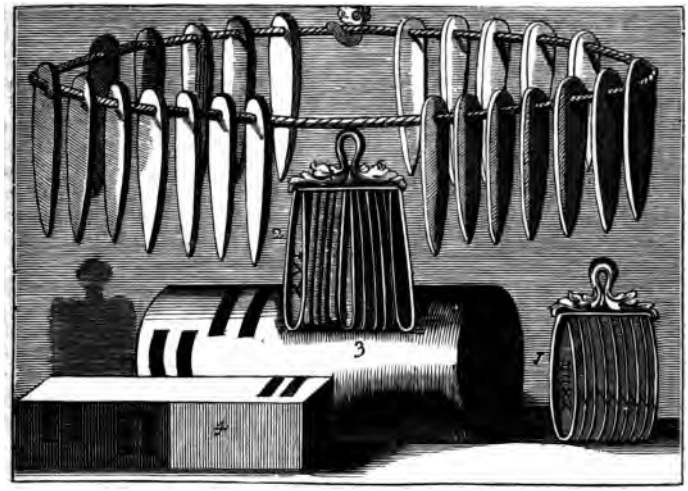


Fig. 119. "2. *The Proportion of* Touch Needles *for* Gold. 4. *The* Ingot *to be compared with these* Touch Needles; (3) as also by the Touch-stone." (Pettus).

gilder, and soder every one copper piece; after this they touch their gold; and by this they can very well see whether the gold have its right *contents* either in duccats, crowns, or *Rhenish gold;* but if there be a different content, then they cannot know how much properly the content is less."

Pettus also explains "How the touch needles are to be used"—"When thus the touch needles are prepared with diligence, and one would use them, there is need of a good touch-stone upon which the gold is to be touched; of such are found some part which are grey and pale green, but the black ones are best, although the same be not all good, especially if they are either too hard or too weak. The weak ones have this property, that upon them no gold doth touch bright, but the gold doth only grind on it and becometh in the aspect weake and ruffe; also the Hungarish or other weak gold will not touch itself right upon touch-stones, which are too hard for the gold, doth run over it, that the stroak is not very well to be seen, and that touch-stone is not good which doth not touch the gold, of what contents soever it be, with a fine, good, and strong stroak; that it be bright upon it, and also

the touch needles, as long until the same stroak be like the gold stroak in the colour and as high, then ye have very nigh the content of the gold only, as I have given an account above. Observe well whether the gold be high-grained—viz., whether it hath much copper added, or much white, which is called pale gold; according to this use the needles, which every one doth not understand, and therefore he must have the knowledge of the right stroak from great practice. But as to the hard gold, they do not give a right stroak, but they do touch all of a smaller content than they have in fine gold, therefore such stroaks are to be judged false and uncertain."

There is another mode of testing a rock containing gold or some glittering particles, when it is in such a fine state of division that the hammer-and-anvil test for malleability cannot be well applied. This mode is a mere repetition of an old alchemical experiment, which is thus rendered in the books on "The Philosopher's Stone." "*Hide and couple in a transparent denne the eagle and the lyon, shut the doore close, so that their breathe go not out, and strange ayre enter not in. The eagle at their meeting will tear in pieces and devoure the lyon, and then be taken with a long sleepe.*" Such mysterious language appears, no doubt, very unintelligible—quite worthy, it might be thought, of the gipsy at Norwood; but still the language, as a whole, is very appropriate, and admits of an easy interpretation. Thus, we are told to hide the *lyon* and the *eagle* in a *transparent denne*. The alchemist does not say put them into a glass, for how could you get such animals into any ordinary vessel? the appropriate word "*denne*" is therefore used, meaning, of course, a glass receptacle; but what is the *lyon?* It means gold, the king of metals, whilst the *eagle* is the name for quicksilver or mercury. Put some gold leaf into a glass, and add mercury, which immediately unites, amalgamates with, or tears and devours the lion gold. We have now formed a thick amalgam, the quicksilver no longer runs about so quickly on a flat surface, but is pasty and sluggish; hence we complete the alchemists' process, by observing that it is, in their poetical language, "*taken with a long sleepe.*"

The mode of using this plan in practical testing is very simple. Powder say a quarter of a pound of the rock supposed to contain gold on the anvil, place this in a wine-bottle, with a quarter of an ounce of quicksilver, continually shake all together with a little water for several hours, and when a leisure moment is found, separate the quicksilver from the earthy matter, observing if it looks pasty. Place this on a shovel and heat red hot, taking care to avoid the fumes, which are very poisonous, and would soon produce salivation if inhaled. If any gold has been taken up by the quicksilver, it will be left behind on the shovel, and may be scraped off and weighed; a calculation being soon made to determine, by rule of proportion, the per-centage of gold in the rock.

Should the examiner wish to economize his quicksilver, he must squeeze the amalgam through a piece of wash-leather before heating on the shovel; the fluid matter that passes through is the mercury, which

will do again; the pasty matter, if any be left in the leather, is the gold amalgam, which can be heated as already directed.

Whilst alluding to alchemical processes in connexion with gold, another may be quoted, with its accompanying illustration, which has been faithfully copied from a work written by Basil Valentine, being "A Practick Treatise, together with the Twelve Keys and Appendix of the Great Stone of the Ancient Philosophers."

Fig. 120. The Purification of Gold by Fusion with Antimony.

"The king's diadem is made of pure gold, and a chaste bride must be married unto him; wherefore, if ye will work on our bodies, take the most ravenous grey wolf, which by reason of his name is subject to valorous *Mars*, but by the genesis of his nativity he is the son of old *Saturn*, found in mountains and in vallies of the world. He is very hungry, cast unto him the king's body, that he may be nourished by it; and when he hath devoured the *king*, make a great fire, into which cast the *wolf*, that he be quite burned, then will the king be at liberty again; when ye have done this thrice, then hath the *lion* overcome the *wolf*, neither can he find any more on him to feed upon, and so is our body prepared for the beginning of the work."

The whole of this process may be reduced to very few words, and it

simply means the purification of gold (the king's body) by the sulphuret of antimony (the most ravenous grey wolf), which in the mineral state of sulphuret is decomposed by iron filings at a proper heat (or is subject to valorous Mars, or iron). By fusion with the metal antimony the impurities are removed from gold, although that metal takes up a certain proportion of antimony, and must be purified subsequently by fusion and blowing air on it. It must be placed with lead in the cupel or test; to use the language of the alchemical process, "when he [the antimony] hath devoured the king [the gold], make a great fire, into which cast the *wolf*, that he be quite burned [separated as oxide], then will the king be at liberty again [or the gold be reduced to the metallic state]."

Pettus gives full directions for casting gold through antimony, which he says "is a very old invention," so that the gold by it may be made very clear and fine; but he adds, "so it is not well to trust to this, that the gold should always come out sure and very clean." The apparatus used in 1686, and described by Pettus, is almost exactly that which is employed at the present time; and the next cut is Pettus' sculpture (so called), showing how the *cup*, *ingot*, and other *instruments* to the casting through are to be formed.

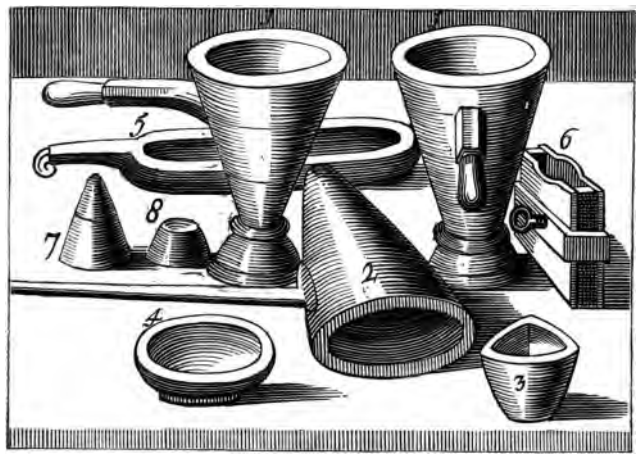


Fig. 121. 1. "The form of the common cup cast in brass. 2. A cup made of smith's work [to receive the melted antimony and gold]. 3. A crucible for the work [*i.e.*, the casting the antimony and gold]. 4. A flat test [cupel] for it. 5. The ingot [mould]. 6. The plates [mould]. 7. The cast antimony with a gold regulus. 8. The cast antimony when the gold regulus is beaten from it." (Pettus.)

Amongst the various methods of determining whether a substance with the outward appearance of gold is really the precious metal, none are

more satisfactory than the test of "specific gravity," which, reduced to its most simple definition, means "the weight of equal bulks;" but, as it would be difficult to prepare exact measures (say cubic inches or cubic feet) of the metals, the method first devised by Archimedes is always employed.

Thus a cubic foot of water weighs just 1000 ounces at a temperature of 60° Fah., the same bulk of gold weighs 19,300 ounces; now, as water is the standard unit or starting-point to which the weight of the volumes of all other solids is referred, the specific gravity of water being 1, that of gold will be 19·3, or gold is more than nineteen times heavier than water. It has, however, been stated, that exact volumes of solid substances could not be prepared; but if the specific gravity is determined by reference to one standard (water), and every solid, whatever may be its shape, actually compared with its own bulk of water, then we have a method against which no mechanical difficulties can be adduced.

Every substance weighed in water weighs less than it does in air, and this loss is found to be precisely equal to the weight of the volume of water which it displaces; for instance, a cubic foot of gold weighs in the air 19,300 ounces, and if thrust bodily into a vessel quite full of water, it displaces a cubic foot of water, which, if collected and weighed, amounts to 1000 ounces; and this is the division, for the rule says, divide the gross weight (19,300) by the loss of weight in water or water displaced—viz., 1000—and the quotient (19·3) is the specific gravity.

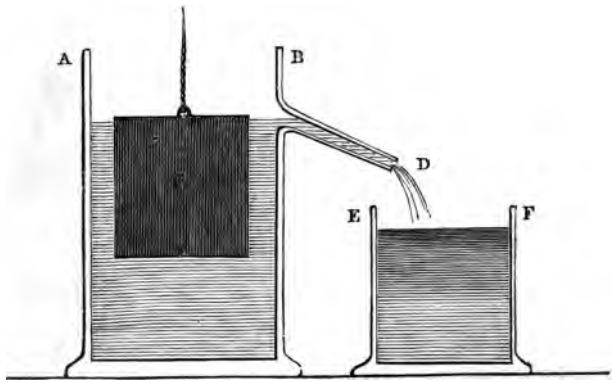


Fig. 122. The Principle upon which the Specific Gravity of a Solid is taken. A B. Vessel full of water. C. The cubic foot of gold placed in the water. D. The cubic foot of water displaced, and flowing into the vessel, E F.

The loss of weight is of course more apparent than real, and is due to the upward pressure of the water, by which a portion of the weight

of the body equal to the weight of the bulk of the water which it displaces, is sustained. To put this principle in practice, a delicate balance should be provided, with the strings of one scale shorter than the other; and this latter pan may have a hook inserted, for the convenience of suspending a thread or horsehair from it. The experiment can be made with a sovereign, which is suspended by a horsehair to the hook of the shorter stringed scale pan, and is found to weigh 123·24 grains. A glass vessel containing distilled water is now placed under the latter, so that the sovereign is completely surrounded with water, and if air-bubbles adhere, they may either be cleared away with a feather; or, what is still better (with gold and other metals and minerals to which air adheres), is to dip them first in alcohol, and then in water, which effectually removes the adhering air, and causes the water to be in perfect contact with the metal. The sovereign will now be found to weigh 116·34 grains.

Fig. 123. Mode of taking the Specific Gravity of a Sovereign. A B. The delicate balance. C. Vessel containing distilled water. D. The sovereign suspended by a horse-hair.

Weight of the sovereign in air	123·24
„ „ in water . . .	116·34
	6·90

The weight of the sovereign in air (123·24) divided by the loss of weight in water (6·9) gives a quotient of 17·86, being the specific gravity of the gold, which is alloyed with copper, and therefore weighs less than pure gold. The standard for coin is twenty-two carats fine; that is to say, it consists of twenty-two parts of pure gold and two parts alloy.

Table of the Specific Gravities of the Metal in common use at 60° *Fahrenheit.*

Platinum	20·98
Gold	19·26 to 19·3 and 19·64
Mercury	13·57
Lead	11·35
Silver	10·47 to 10·5
Bismuth	9·82
Copper	8·89
Iron	7·79
Tin	7·29
Zinc	6·5 to 7·1

This simple rule may be applied to all metals of any size or weight, always taking the precaution to clear away with a feather the air bubbles which attach themselves to the different substances.

When, however, the gold is associated with quartz, another rule must be made use of, being a modification of the first, which I can recommend, having verified it in practice with some nuggets kindly lent by Messrs. Hunt and Roskell, of Bond-street.

Practical Method of determining the respective Quantities of Gold and Quartz in a Nugget.

$$\frac{\text{S. G. Nugget}-\text{S. G. Quartz}}{\text{S. G. Gold}-\text{S. G. Quartz}}\times\frac{\text{S. G. Gold}}{\text{S. G. Nugget}}\times\text{weight of nugget}=\text{weight of gold in nugget.}$$

$$\frac{\text{S. G. Gold}-\text{S. G. Nugget}}{\text{S. G. Gold}-\text{S. G. Quartz}}\times\frac{\text{S. G. Quartz}}{\text{S. G. Nugget}}\times\text{weight of nugget}=\text{weight of quartz in ditto.}$$

To make use of the above formulæ or rules, the reader need know nothing whatever of algebra. He has only to be acquainted with the management of vulgar fractions; and he must notice that — is the sign of subtraction; × is the sign of multiplication; and S. G. stands for specific gravity. For instance,

Ex. I. Suppose we have a nugget weighing 1000 grains, and its specific gravity is found to be 8. Suppose also the specific gravity of gold were 18, and that of quartz 2. Then, by above rules,

$$\frac{8-2}{18-2}\times\frac{18}{8}\times1000=\frac{6}{16}\times\frac{18}{8}\times1000=843\tfrac{3}{4}\text{ grains of gold in nugget.}$$

$$\frac{18-8}{18-2}\times\frac{2}{8}\times1000=\frac{10}{16}\times\frac{2}{8}\times1000=156\tfrac{1}{4}\text{ grains of quartz in ditto.}$$

Ex. II. Suppose an Australian nugget is brought to us, weighing 10 ounces troy, and we find its specific gravity to be 8·5. Suppose also we take the specific gravity of gold at 19·0, and that of quartz at 2·5. Then, as above,

oz. troy.

$$\frac{8\cdot5-2\cdot5}{19\cdot0-2\cdot5}\times\frac{19\cdot0}{8\cdot5}\times10=\frac{6}{16\tfrac{1}{2}}\times\frac{19}{8\tfrac{1}{2}}\times10=8\cdot128342246\text{ of pure gold in nugget.}$$

$$\frac{19\cdot0-8\cdot5}{19\cdot0-2\cdot5}\times\frac{2\cdot5}{8\cdot5}\times10=\frac{10\tfrac{1}{2}}{16\tfrac{1}{2}}\times\frac{2\tfrac{1}{2}}{8\tfrac{1}{2}}\times10=1\cdot871657754\text{ of quartz in ditto.}$$

It may be presumed that this practical mode of estimating the value of gold nuggets is clear and brief, and as short a rule as it is possible to conceive. Moreover, it is grasped by the eye all at once—you see the whole; besides which, it is cast in a perfect mathematical mould, and must therefore be absolutely and universally true; also capable of instant application to every conceivable example.

By giving the two formulæ, one for the gold, and the other for the quartz, we give the reader the readiest possible mode of *proving* his own work; thus having (Ex. I.) found the gold in nugget to be 843¾ grains, he deducts this from the whole weight, and gets 156¼ grains of quartz for a remainder. He therefore now works by the second formula to obtain the weight of quartz; and finding it to come (by the independent rule) exactly 156¼ grains, he has reason to conclude that his work is altogether right.

Ex. III. Let the specific gravity of gold be 19·26, and that of quartz 2·6. An Australian nugget, weighing 550 grains, and assumed to contain nothing but gold and quartz, was found to have the specific gravity 9·77. Required the quantity of gold and quartz respectively in the nugget.

Let x=grains of gold

$\therefore 550-x$=grains of quartz.

Then, since gold loses $\frac{1}{19\cdot26}$ of its weight in water,

and quartz loses $\frac{1}{2\cdot6}$ ditto ditto,

and also nugget—$\frac{1}{9\cdot77}$ ditto ditto,

therefore $$\frac{x}{19\cdot26}+\frac{550-x}{2\cdot60}=\frac{550}{9\cdot77}$$

And solving this equation, we have

x=466·6256 grains of gold in nugget }
and $550-x$= 83·3744 grains of quartz in ditto } Answer.

Having shown how gold may be distinguished when disseminated through quartz or other earthy or mineral matter, it will be advisable to conclude this chapter with the chemistry and technical applications of gold.

First Series of Experiments.

Pure gold has a specific gravity of 19·3, and its equivalent of combining proportion is 197. It is prepared by dissolving, say, a half-sovereign in a mixture of one part nitric acid and 4 parts hydrochloric acid. The coin and the mixed acids are placed in a clean Florence oil flask, and gently heated by the spirit lamp until the gold disappears. If any silver is present, it is found at the bottom of the flask in the state

of an insoluble chloride, and therefore the solution is diluted with distilled water and filtered. The filtered liquid is then carefully evaporated till a drop taken out and placed on a cold plate solidifies; water is again added, and the solution boiled with some pure sulphate of iron, when the gold precipitates and sinks to the bottom of the vessel. The dark powder should now be well washed with water, boiled with hydrochloric acid, and again edulcorated, and care of course must be taken, in the first place, to add enough sulphate of iron, in order that all the gold may be precipitated in the metallic state. The gold powder when dry appears almost like brown-red earth, but when rubbed or burnished with a piece of steel, or other hard substance, very soon shows its nature. Some chemists prefer boiling the terchloride of gold with oxalic acid instead of with sulphate of iron, as the flakes of precipitated gold are larger, more coherent, and more easily manipulated with in the subsequent processes of boiling with hydrochloric acid and washing with water; but when oxalic acid is used, all excess of acid must first be removed from the terchloride.

Second Series.

To show the perfect insolubility of gold in the mineral acids, some of the powder obtained from the last experiment may be placed in three separate glass test tubes, one of which contains nitric, the second hydrochloric, and the third sulphuric acid. The finely-divided gold may be boiled for any length of time in either of these acids, and no solution takes place; but directly the nitric and hydrochloric acids are mixed, then the gold is attacked and disappears, and if the solution is carefully evaporated till it solidifies, pure terchloride of gold is formed.

Third Series.

Oxygen unites with gold in two proportions, and forms with the metal

Protoxide of gold, AuO.
Teroxide of gold (auric acid), AuO_3.

These combinations do not occur by the direct union of oxygen with the metal, and indeed, with the exception of chlorine, bromine, fluorine, and phosphorus, no other non-metallic element unites directly with gold. Oxide of gold (AuO) is obtained by decomposing the protochloride of gold with a dilute solution of potash. The protochloride is prepared by heating the terchloride of gold ($AuCl_3$) obtained in the second experiment, above, to a temperature of 393° Fah. There are two chlorides of gold, viz., the chloride and terchloride.

Fourth Series.

Purple of Cassius, termed by Gmelin stannate of aurous oxide (AuO,SnO_2,SnO,SnO_2+4HO), being a double stannate of gold and tin with four equivalents of water, is prepared in various ways; perhaps the most simple one is to dissolve the pure terchloride of gold mentioned in the second experiment, in an abundance of water. If pure ter-

chloride has been obtained from a half-sovereign, which weighs about sixty grains, it may be diluted with at least six ounces of water, and then placed in contact with pure granulated tin, when a purple precipitate is obtained, which must be well washed with water and dried by a gentle heat. The Purple of Cassius is a vitrifiable pigment, and employed for imparting the ruby red to glass and porcelain.

Fifth Series.

To prepare jeweller's gold, melt, in a good crucible, with a little borax, three parts of pure gold, and add thereto one part of copper. Gold for coin consists of eleven parts of pure gold and one part of copper.

Sixth Series.

China is gilt by first triturating gold leaf with turpentine and borax, and then laying this mixture on the porcelain, which is subsequently brought to a proper heat in an oven or muffle surrounded with burning coal.

Ordinary gilding, such as that of picture-frames, is performed by first laying on a tacky, sticky varnish, called gold size, to which the gold leaf firmly adheres, and when hard and dry can be washed with soap and water; but if the gold leaf is only laid on with parchment size or gum, it is easily affected by water, and may soon be washed off.

Seventh Series.

Water gilding, so called (being a most pernicious process to those engaged in it), is conducted by first preparing an amalgam of gold and mercury. The copper article is then cleaned with dipping acid, composed of equal parts of nitric and sulphuric acids, well washed with water and placed in a solution of nitrate of mercury, when metallic mercury is precipitated upon and adheres to the copper. The amalgam of gold is then carefully spread over the amalgamated copper surface, and the article is placed in a proper oven or muffle heated to about 700° Fah., when the mercury volatilizes and a beautiful coating of dead gold remains behind. When this operation is conducted on the large scale, care is taken to get rid of and condense the fumes of mercury; and indeed this dangerous process is now happily almost entirely superseded by electro-gilding.

Eighth Series.

When terchloride of gold is dissolved in sulphuric ether, the solution may be employed for ornamental gilding on cutlery, or writing initials or names on steel articles. It is also sometimes used to preserve the sharp points of steel surgical instruments from rusting. The best mode of preparing the ethereal solution is to dissolve the terchloride of gold first in a little water and then to shake some ether with it in a long tube, and the two liquids, viz., the ether containing the chloride of gold and the remaining water solution can afterwards be separated by

decantation. The ethereal solution of the terchloride of gold should be kept in a dark place or opaque bottle.

The gilding by the ethereal solution of gold is not, however, very permanent, and therefore polished steel is gilded with gold leaf. The steel is just heated till it takes a bluish tint, a first coat of gold leaf is now applied, which is pressed gently down with a burnisher and then exposed to a gentle heat. Several leaves, either single or double, are thus applied in succession, and the last is burnished down cold. A fine illustration of this kind of gilding is shown in the annexed cut. (Fig. 124.)

Fig. 124. Wilkinson's Exhibition Sword, ornamented with precious stones and gold devices. The blade is of the finest temper, and combines embossing with engraving, bluing, and gilding, so as to form two elevations of a highly ornamental pattern. (*Art Journal.*)

Ninth Series.

Books are gilt and lettered by means of heated metal stamps of the letters or devices; these are pressed on the cover, which is previously dusted with powdered resin, and the gold leaf laid over it. Wherever the hot stamp touches, the resin melts and the gold adheres to it, and the remaining leaf is dusted off with a brush.

Tenth Series.

Gilding by the wet process may be conducted in various ways, and the metal, of course, is first reduced to a soluble state by conversion into terchloride.

Process of M. de la Rive.—Pour a solution of chloride of gold exactly neutralized with carbonate of soda, and containing only a very small quantity of gold, into a glass cylinder whose lower extremity is hermetically closed with moistened gut skin, and introduce

the cylinder into a vessel which contains some water very slightly acidulated with a few drops of sulphuric acid. The cylinder should be supported so as to prevent its lower surface from resting immediately on the bottom of the larger vessel. It is necessary to carefully clean, or even polish the surface of the metal, whether of silver or brass, that we desire to gild, lest a portion of it should be left ungilt. To attain this end it is sometimes advisable to place the metal for a few minutes in contact with zinc in dilute sulphuric acid, so that hydrogen may be disengaged on its surface; after which it must be well washed. In order to gild an object, it must be fixed or suspended by a platinum wire, to the other extremity of which is attached a plate of zinc; this done, plunge the article to be gilt in the solution of gold and the zinc plate in the acidulated water. The power of the electric current may be moderated at will by immersing more or less of the zinc plate, so that no hydrogen may be disengaged, and that in this case the chloride of gold is alone decomposed. After a minute the article to be gilt is withdrawn, wiped dry with a fine linen cloth, rubbed a little, and again immersed. After two or three immersions the metal will be found sufficiently gilded. By the above process it will be noticed that the gilding is conducted with the chloride of gold only, no cyanide of potassium being used; and the article to be gilt must not be left for a moment in the gold solution without galvanic connexion, otherwise it will not be gilt at all or the gilding will be very bad. It is, therefore, advisable to place the zinc in the acid first, and then to bend down the wire to which the article is fixed into the solution of chloride of gold. The solution of gold should be diluted with water until a plate of silver dipped into it no longer acquires a black coating, but exhibits a bright yellow colour on being rubbed. Steel pens, freed by dilute hydrochloric acid from their blue film of oxide, may be gilt without the aid of galvanism by simply immersing them in the gold solution neutralized as above with carbonate of soda.

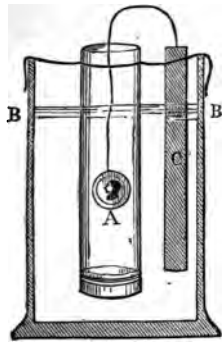


Fig. 125. De la Rive's Process of Gilding. A. Lamp chimney closed at the lower end with bladder containing the solution of chloride of gold; it is supported so that the bladder end does not touch the bottom of B B, the outer vessel, containing the acidulated water. C. The plate of zinc attached by a wire to the article which is to be gilt.

Eleventh Series.

The following method of gilding is said to give the best results. The gold solution is prepared by dissolving one part of the terchloride of gold and ten parts of ferrocyanide of potassium in one hundred parts of water, which is filtered from cyanide of iron, and mixed with one hundred parts of a saturated solution of ferrocyanide of potassium, and the

whole diluted with an equal or double portion of water; the more dilute the solution, the brighter is the frosted gilding produced, and it is placed in a porous vessel or glass tube, closed with bladder. In the outer vessel, containing the zinc plate, is placed a solution of ordinary ferrocyanide of potassium and common salt; the latter salt alone, acts more quickly, but for gilding silver, the solution must not contain too much common salt, otherwise the silver will be blackened by the formation of chloride. It is advantageous to have the two solutions—viz., the one in the porous vessel, and the other in the outer cell—of the same level and specific gravity, so that they may not mix *too* easily. The zinc must not be amalgamated, otherwise chloride of mercury will be introduced into the gold solution, and may be reduced on the metal. The vessel containing the gold may be either a tube closed with bladder, or an inverted gas jar of which the neck is tied over with linen and a layer of clay free from lime and moistened with a solution of common salt and about a quarter of an inch thick, placed above or on the linen, so that it represents the bottom of the vessel containing the gold. While the gilding is going on the object is frequently moved, in order to keep the very dilute solution of gold as nearly as possible in one uniform condition. If the deposition goes on too slowly, an additional quantity of common salt is added to the liquid in the outer vessel containing the zinc plate. Warming the outer vessel in a water bath to 68° or 77° Fah. likewise accelerates the gilding, but diminishes its lustre. If any of the gold solution penetrates into the outer vessel, and gold is in consequence precipitated upon the zinc, it must be removed. A thin deposit of gold makes its appearance in ten minutes; to produce a thick deposit several hours are necessary. The gilding on silver is first greenish, then, yellow, then, after twelve hours, reddish yellow. Brass and bronze take the gilding much more quickly. Finally, the gilt object is washed with dilute sulphuric acid, which removes any iron that may perchance have been precipitated, and then rubbed with leather. The articles to be gilt are either cleaned by being dipped into

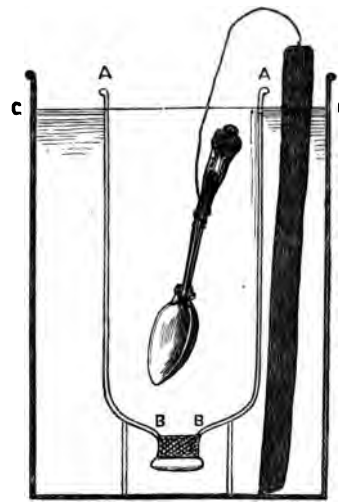


Fig. 126. A A. Inverted gas jar. B B. Neck of jar closed with linen and clay; the jar contains the solution of gold. C C. The outer earthen vessel containing the solution of ferrocyanide of potassium and chloride of sodium; also the plate of zinc *not amalgamated*, and attached by a platinum wire to the spoon.

dipping acid and well washed with water, or they are first well burnished and then thoroughly cleaned by rubbing with lampblack moistened with concentrated nitric acid and spread upon linen; then dipped rapidly in water, and again rubbed, and so on, until perfectly clean, when they are well dried.

Twelfth Series.

Process of Walker.—Terchloride of gold is dissolved in cyanide of potassium, and an independent small battery used. The article to be gilt is first cleaned, and then connected with the negative element, whilst a small sheet of gold is connected with the positive; both are placed in the solution of gold, which is thus maintained at one uniform strength; for, as the gold is deposited on the article, it is also dissolved from the gold plate.

Thirteenth Series.

A solution of gold can be made by placing a bit of gold foil in a solution of cyanide of potassium connected with the positive element of a small battery, whilst the negative element is placed in contact with an iron plate enclosed in a porous cell containing some of the same solution

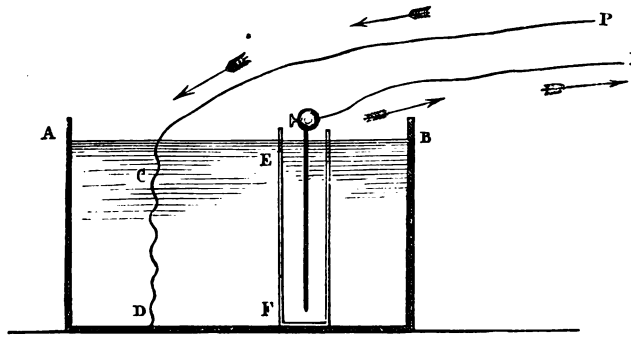


Fig. 127. A B. Vessel containing a solution of cyanide of potassium. C D. The gold foil in connexion with the positive pole of the battery, and immersed in the solution of cyanide of potassium. E F. A porous cell, also containing cyanide of potassium solution, and a plate of iron connected with the negative pole of the battery. The arrows show the direction of the current.

of cyanide of potassium, and of course standing in the same vessel with the foil of gold. Napier recommends that the solution of gold should be heated to a temperature of 130° to 150° Fah. in a water bath, which enables the gilder to employ less battery power. The battery for dissolving the gold foil may consist of five pairs of Smee's arrangement and of two or three for gilding small articles; the gilding solution should contain about half an ounce of gold to the gallon. Napier de-

scribes the deleterious nature of the gases, cyanogen and hydrogen, which are evolved during the electro-gilding process on the large scale, and recommends abundant ventilation, with the use of large rooms. Even amateurs are warned not to keep their small experiments performed in tumblers in their bedrooms, as the practice is decidedly dangerous.

Fourteenth Series.

The tests for gold have already been partly described in the first portion of this article on gold, but they are here placed together for the use of those who wish to know how to distinguish gold by chemical reagents.

The chlorides of gold are all yellow, and their solutions present gradations of yellow up to the highest points of dilution.

Potash in excess does not precipitate gold, but a small quantity in concentrated solutions of gold, with the assistance of heat, throws down a reddish yellow precipitate, the teroxide of gold, AuO_3.

Ammonia produces, in strong solutions of gold, a similar coloured precipitate of aurate of ammonia, or fulminating gold.

Sulphuretted hydrogen precipitates from acid and neutral solutions of gold the whole of the gold which they contain as black sulphuret of gold, AuS_3, insoluble in potash, or in any single acid, but soluble in alkaline sulphurets and in aqua regia.

Hydrosulphuret of ammonia produces the same result, and in excess re-dissolves the precipitate.

A solution of protochloride of tin warmed with a few drops of nitric acid, produces with a solution of gold the well-marked precipitate of purple of Cassius, which is insoluble in hydrochloric acid.

A solution of protosulphate of iron reduces the oxide of gold to the metallic state, and precipitates it as a reddish-brown powder, which, being collected, boiled with hydrochloric acid, and well washed and dried, may be pressed and burnished, and will show the colour and brilliancy of gold on any hard surface, such as a touch-stone or bone.

The very finely-divided gold thrown down by the protosulphate of iron appears blue or blackish blue by transmitted light; and this is apparent even when 40,000 parts of liquid are used to one of terchloride of gold. When the dilution is doubled, or 1 in 80,000 parts, the colour is sky-blue; 1 in 160,000 parts, violet; 1 in 320,000, the violet tint is still recognisable, but is difficult to appreciate when the dilution is carried to 1 in 640,000 parts.

Fifteenth Series.

An amalgam composed of half an ounce of gold and one hundred pounds of mercury is liquid, and may be completely squeezed through leather. But if four ounces of silver be likewise dissolved in the mercury, and the product pressed through leather, 28½ ounces of amalgam remain in the leather, containing the half-ounce of gold and 3¾ ounces of silver. The whole of the gold, together with the greater part of the silver, is, therefore, separated in the form of a solid amalgam.

Sixteenth Series.

White silk may be gilt by wetting it with a solution of terchloride of gold, and then exposing the silk to the action of sulphurous acid gas, which may be easily obtained by burning a little sulphur under a jar, and confining the vapour. The silk is covered with a coating of minute particles of gold in a very short space of time.

Another pretty experiment, illustrating the reduction of gold from its combination with chlorine, and called many years ago "the mineral rainbow," may be produced by pouring a small quantity of a solution of terchloride of gold into a dish, plate, or cup containing some ether in which phosphorus has been dissolved; the gold is instantly reduced in exquisitely thin films, presenting purple, blue, and red colours, with more or less metallic brilliancy.

Seventeenth Series.

Three parts of sulphur and three of caustic potash dissolve one part of gold when boiled with it in water. This is the process of Stahl, and is the one he supposed Moses was acquainted with when he reduced the golden calf to a fine powder, and made the Israelites drink it. This idea of Stahl's is refuted by the words of the text, as already quoted at p. 118.

Fig. 128. Votaries dancing round the Golden Calf (N. Poussin).

Fig. 129. 1. Assayer. 2. The scales. 3. The cases for weights. 4. Glasses for aqua regia, aqua fortis, aqua vitrioli, aqua argentum, and quicksilver. (Pettus.)

CHAPTER V.

SILVER. ☽

The semicircle is the image of the moon, the only planet that appears under that aspect to the unassisted eye.

ALTHOUGH the metamorphic and granitic rocks are destitute of organic remains, they are traversed by numerous mineral veins, some of which are probably gold (although no one has yet been fortunate enough to arrive at a vein of the latter metal), some of silver, others of various mineral veins, containing lead, copper, nickel, antimony, zinc, whilst tin ores appear to be specially confined to granitic rocks.

Many years ago a vein of silver ore was wrought with considerable profit in the parish of Alva in the county of Stirling. The metalliferous minerals were native silver, and silver glance, sulphide of silver, with ores of copper and cobalt; and the vein stones were calcareous spar (carbonate of lime), and heavy spar (sulphate of baryta). It is said that the value of the silver extracted amounted to forty or fifty thousand pounds sterling.

Native silver has been met with in various parts of Cornwall, and is associated with galena (sulphuret of lead), iron pyrites (sulphuret of iron), bismuth, cobalt, and wolfram (tungstate of iron), in veins traversing clay slate. In Europe, perhaps the most celebrated silver mine is that of Königsberg in Norway, in the neighbourhood of Mount Johnskunden, which towers up to the height of more than 3000 feet. The mines were first worked in the year 1624; the deepest is 180 fathoms, and out of it was taken an enormous mass of native silver, now in the Museum of Natural History at Copenhagen, measuring six feet long, two feet broad, and eight inches thick, and estimated to contain five hundred pounds' weight of pure silver.

In Europe silver occurs in Sweden, Saxony, Bohemia, Silesia, Swabia, Wirtemberg, also in France, Spain, Hungary, and Transylvania. In Asia, Siberia, and especially China, where silver constitutes the chief portion of the currency. Silver mines are worked in North and South America; Mexico, Peru, and the mines of Gualgayoc, and those of other localities in the same quarter of the globe, are the most celebrated sources of silver. Humboldt asserted that the mines of Mexico and Peru afforded more than 316,000,000 lbs. troy of silver in the course of three centuries, and he also remarks that this silver would form a solid sphere of a diameter of 91,206 feet. M. Brongniart, a French mineralogist, has ascertained the average annual quantity of silver supplied from the following localities between the years 1790 and 1802.

Old World.

Asia:—		
Siberia	40,200 lbs. troy.	
Europe:—		
Hungary	46,000	„
Austrian dominions	11,000	„
Harz and Hesse	11,000	„
Saxony	22,000	„
Norway	22,000	„
Sweden, France, Spain	11,000	„
Total Old World	165,000 lbs. per year.	
North America	1,400,000	„
South America.	885,000	„
Total from America	2,285,000 lbs. per year.	

Notwithstanding this large supply of silver, it would appear to be used almost as quickly as it is produced, and it is absorbed and lost sight of—we must not say destroyed—by the wants of the various civilized communities; such as the hoarding of coin and family plate, the

use of silver in medicine, and also in the arts of electro-plating and photography. It has been said that the ocean may contain a little of everything soluble in water, and it is curious to find, from the experiments of foreign chemists, that sea water contains an appreciable quantity of silver in solution. Malaguti, Durocher, and Sarzeaud have ascertained that a small quantity of silver occurs in sea salt. Sea water itself contains about one milligramme in one hundred litres; various

Fig. 130. *Fucus serratus* and *Fucus ceramoïdes*, which contain $\frac{1}{100000}$ of silver, from specimens kindly supplied by Mr. Boswarva, of Plymouth.

seaweeds, the *Fucus serratus* and *F. ceramöides* (Fig. 130), contain at least $\frac{1}{100000}$; it is also present in chemical products for the preparation of which common salt is used, as, for instance, in carbonate of soda and hydrochloric acid. Silver is likewise found in the ashes of land plants, and the insoluble portion contains more silver than the soluble portion; the ash of ox-blood, rock salt, and most probably coal also, contains minute traces of this precious metal. As gold chiefly occurs in the metallic state, the processes by which it is separated from its matrix or from the alluvial deposits through which it is disseminated, are by no means complicated; but with silver, which is much more plentifully distributed in the mineralized than in the metallic state, the metallurgical processes by which it is procured in a purer form are more

Fig. 131. Native Silver.

complicated and ingenious. Silver is found in about fifteen different species—viz.:—

1. Native silver.
2. Native amalgamated silver and mercury . . . . . { Silver and from 13 to 64 per cent. of mercury.
3. Auriferous native silver . . { Silver and about 28 per cent. of gold.
4. Antimonial silver . . . . { Silver and from 11 to 25 per cent. of antimony.
5. Arsenical silver ore . . . { Silver and about 35 per cent. of arsenic, with iron and antimony.

6. Bismuthic silver ore . . .	Silver and about 27 per cent. bismuth, with lead, iron, copper, and sulphur.
7. Horn silver, or native chloride of silver.	
8. Silver glance, sulphuretted silver, or vitreous silver .	Silver and from 15 to 25 per cent. of sulphur.
9. Brittle or black silver ore, or brittle sulphuretted silver, or brittle silver glance . .	Silver and sulphur, antimony, iron, copper, arsenic, and earthy matters.
10. Red silver ore	Silver, oxide of antimony, and sulphur.
11. White silver ore or white silver.	Silver, lead, antimony, iron, sulphur, aluminum, silica.
12. Grey silver ore, or carbonate of silver.	Silver, carbonic acid, antimony, and copper.
13. Eucairite	Silver, copper, and selenium.
14. Iodide of silver.	Silver and about 23 per cent. of iodine.
15. Bromide of silver	Silver and about 12½ per cent. of bromine.

The most important metallurgical processes by which silver is procured chiefly from the native silver ore and the sulphurets of silver and lead may be arranged as follows:—

No. 1.

Amalgamation with mercury, after treating the powdered silver ore with salt and sulphate of copper, by the Mexican and the European methods.

No. 2.

The silver ore, after being roasted alone or with salt, is subsequently treated with metallic copper.

No. 3.

The reduction of lead ores, the crystallization of the lead, and the final separation of the silver on the cupel by the very ingenious process of Pattinson.

The Mexican amalgamation process is said to have been invented by a miner of Pachuca, called Bartholomew de Medina, and it dates from the year 1557, although some authors assert that it was practised long before in Germany. The ore is first reduced to powder by stamps, and then transferred, after being sifted, to the crushing-mills, or stones moving in troughs with water. Each mill is called *arrastras*, and grinds from eight to ten hundredweight of mineral in about twenty-

four hours. If the ore is rich in silver, so much care is not used in reducing the mineral to powder; it is sufficient if it be reduced to about the fineness of sand. When the ore, in the state of fine mud, is thought

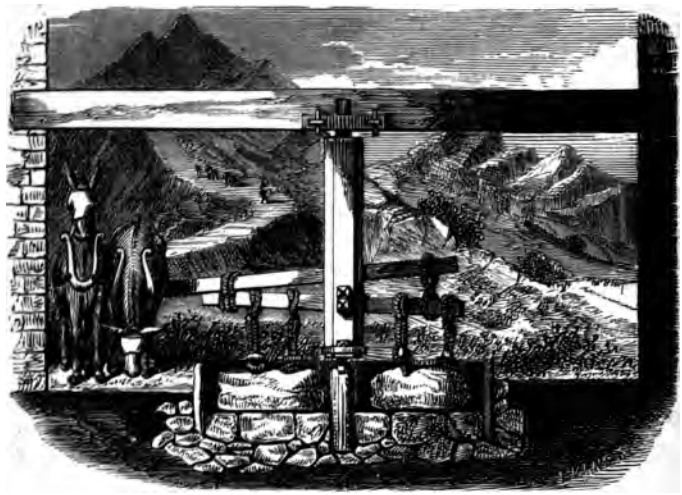


Fig. 132. A Crushing Mill used in Mexico.

to be fine enough, it is carried while yet wet into the amalgamating yard which is paved with large stones. It is then heaped up in masses of from twenty to thirty hundredweight, and forty or fifty of these heaps are called a *tourte*. This quantity is then left to itself for a considerable time, after which common salt is added, in the proportion of from four to twenty per cent., according to the quality of the ore. If the ore does not contain, as it sometimes does, pyrites and sulphate of iron, this substance is also added, mixed with roasted copper pyrites or crude sulphate of copper, called *magistral*, and finally, lime and vegetable ashes are put on the heap. These different substances are trodden together by horses, and being carefully mixed, are allowed to remain together for several days. According to the nature of the ore, their action on one another varies. If the mineral contains naturally the sulphates of copper and iron, or contains much chloride of silver, the heat generated is too great, and is diminished by a further addition of lime. If much sulphuret of lead is present, or the pyrites difficult to decompose, the chemical action is feeble or does not take place, and must be promoted by augmenting the temperature. Then also *magistral*, or

a mixture of sulphate of iron and copper is added. The operation is thought to go on well when a portion of the mixture, on being placed in the hand, causes a sensation of heat. A few days afterwards, about six times as much mercury as the *tourte*, or torta, is supposed to contain silver is added, as well as more magistral. The mercury is allowed to filter through a bag made of coarse canvas, which causes it to escape in innumerable small jets over the whole surface of the heaps, and the whole is again thoroughly incorporated by driving twelve or twenty mules round it for several hours, or a considerable number of barefooted workmen march backwards and forwards in this metallic and mercurialized mud. What the effect may be on the health of the men and animals is not stated, although it can easily be conceived that it must be prejudicial.

Every day the overseer ascertains the progress of the work by washing a portion of the mixture in a wooden bowl, and judging by the aspect of the amalgam. When the mercury assumes the colour of ashes, separates in a grey powder, and sticks to the fingers, the heat is too great, and more lime is added. If, on the contrary, the mercury retains its metallic lustre, or is covered with a red or golden scale, if it does not appear to act on the mass, the heat is increased by the addition of magistral.

The process is very tedious, and lasts about five months; and when the amalgamation is judged complete, the *mud* is thrown into troughs, made either of stone or wood, in which the arms of a mill revolve so as to stir it; a stream of water passes through, and the lighter earths and the oxides are carried away, and the amalgam which remains at the bottom is put into a strong leather bag with a canvas bottom, through which the mercury penetrates, whilst the pasty amalgam remains behind; it is then subjected to a gentle pressure, and moulded into wedge-shaped masses, each weighing about thirty pounds. The remaining mercury is then distilled off, and the silver is finally cast into bars. The *rationale* of the process depends on the mutual decomposition of the salt and sulphate of copper, which are converted into sulphate of soda and chloride of copper; the latter is acted upon by the metallic silver, and a subchloride of copper produced, with the formation of chloride of silver. The subchloride of copper dissolved in the solution of common salt reacts on the sulphuret of silver with the formation of more chloride of silver and sulphate of copper. The mercury is partly changed by contact with the chloride of silver into subchloride of mercury, whilst the metallic silver amalgamates with the excess of mercury. To prevent the formation of free protochloride of copper, which causes a great loss of mercury, by converting it into chloride of mercury, lime is added for the purpose of decomposing the excess of chloride of copper, and keeping it in the state of subchloride.

The following table exhibits the complicated changes which are supposed to occur, numbered in the order of their succession, water, of course, being present:—

	Materials.		Products.
No. 1	Sulphate of copper . . . Chloride of sodium . . .	= No. 2	Sulphate of soda. Chloride of copper.
No. 3	Metallic silver (in the ore) . Chloride of copper . . .	= No. 4	Chloride of silver. Subchloride of copper.
No. 5	Chloride of sodium . . . Subchloride of copper . . Sulphuret of silver (in the ore)	= No. 6	Sulphate of copper. Chloride of silver.
No. 7	Chloride of silver . . . Metallic mercury . . .	= No. 8	Subchloride of mercury. *Silver amalgamated with mercury.*

Gmelin remarks, "Might not many of the poorer silver ores be treated as follows?—Pounding them finely, washing them if they contain sulphur, and heating them with a quantity of oxide of manganese and hydrochloric acid sufficient to convert the sulphide of silver into chloride, washing thoroughly with water, dissolving out the chloride of silver by ammonia, separating the alkali by distillation, and reducing with sulphuric acid and iron."

The European process of amalgamation is conducted in a much more expeditious and scientific manner by the assistance of heat, and roasting the silver ore and salt together. The roasted ore is sifted and the lumps mixed with more salt and roasted over again. The whole is ground and sifted, the process being finished by the decomposition of the chloride of silver with iron and the amalgamation of the metal with mercury; the latter part of the process is conducted in barrels, which are made to revolve at a velocity depending on the particular stage of the process. (Fig. 133.) In the European, as in the Mexican process of amalgamation, the object is to obtain chloride of silver, which is decomposed, and the metal amalgamated with the mercury. Halsbrücke, a mining village in Saxony, in the vicinity of Freyberg, and about eighteen miles from Dresden, is the site of the most important and complete amalgamation works in Europe.

The refining and desilvering of lead by Pattinson's process is, like nearly all clever and profitable discoveries, one of the most simple that can be conceived, and is based on the principle that pure, or nearly pure lead, crystallizes sooner than an alloy of that metal containing silver. When lead containing silver is melted in a crucible or iron ladle, and allowed to cool slowly, solid particles or crystals form within the fluid lead, which sink to the bottom, and may be easily removed, and when assayed, are found to contain less silver than the remaining fluid portion, which becomes proportionally richer in silver.

This method of extracting silver from lead was discovered by Mr. H. L. Pattinson, at Newcastle-on-Tyne, in 1829, and is said to have been the result of *accident;* but it may be asked, what is the use of these *accidents* happening to most persons? If Pattinson had not been

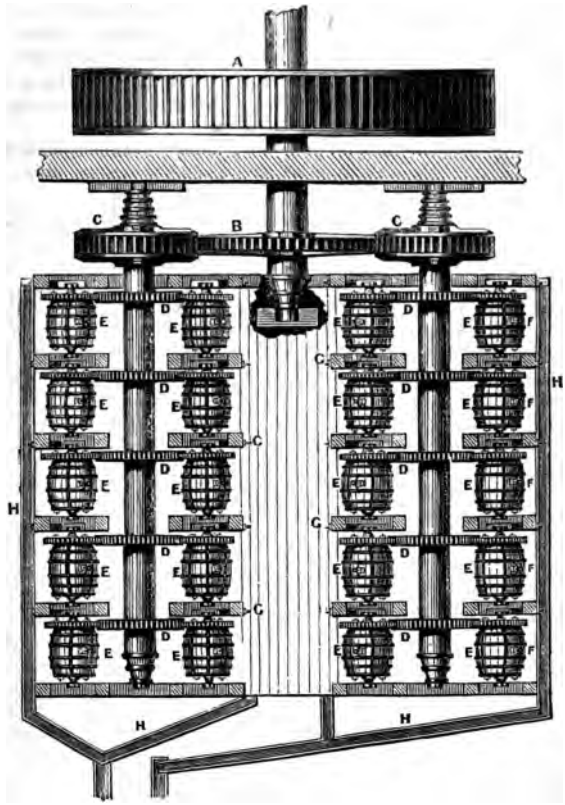


Fig. 133. Amalgamation Barrels. A is the moving wheel; B is another wheel, with 108 teeth on the axle of A; C, C are smaller cog wheels, working to correspond with B, and each of the axles on which they are placed gives motion by means of cog wheels marked D, to a number of amalgamating casks marked E, which are all provided with a half-circular piece of iron marked F, used in conjunction with a screw, to secure the opening of the cask after the materials are put in; G, G, G, G, are also screws, the purpose of which is to enable the workmen to move any of the casks from the contact of the teeth of the wheels marked D, so that it may be worked at without stopping the movements of the other casks; H, H, H, H, indicate the iron gutter which serves to convey the mercury into any one of the casks at pleasure; they are composed of several pieces, which can be moved in any direction. In general there are 20 casks in a set, each of which contains about 300 lbs., or 30 gallons of water, and about 1000 lbs. of the decomposed mineral and pieces of scrap or forged iron. The casks are fastened up and rotated for about an hour; 500 lbs. of mercury are then put into each cask, and it is firmly closed. The machinery is so regulated as to permit the casks to turn round about fifteen or twenty times in a minute. Every four hours the amalgamation is examined, and in about sixteen hours the operation is completed.

gifted with great powers of observation, this valuable principle might have been still unknown, and therefore the credit of the discovery need not be diminished on that account, although it seems to be the fashion to depreciate the merit due to a discoverer if he happens to have wit enough to grasp and apply a new fact which comes accidentally before him. By the old method of separating silver from lead, it was necessary to remove the baser metal by oxidation and conversion into litharge, and then to finish the rich argentiferous lead upon the *test* or cupel. This process might be made profitable with lead which contained from nine to eleven ounces of silver to the ton of lead, but could not possibly pay where the silver amounted to about one ounce per ton; but since the use of Pattinson's process the produce of silver in the United Kingdom has been almost doubled during the last thirty years; and even lead containing a single ounce of silver per ton may be profitably desilvered. Moreover, the trade is greatly increased by the importation of foreign lead, which is subjected to the same process. In order to carry out Pattinson's process, a series of eight or ten moderately shallow cast-iron pans are set in brick-work, with a fireplace beneath each vessel, which

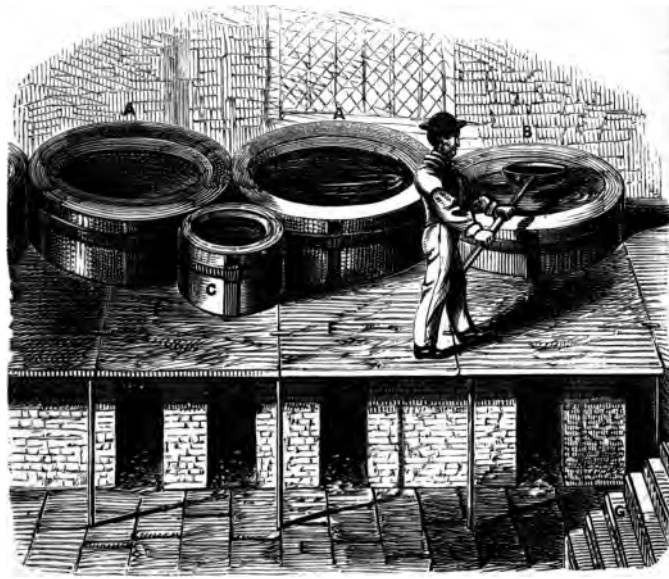


Fig. 134. Pattinson's Process. A A B, iron pans containing the argentiferous lead. C, melted lead to keep the ladle hot.

is capable of holding about five tons of metal. The desilvering is commenced by placing five tons of lead, called *original* lead, and containing, say, ten ounces of silver to the ton, into the middle pot of the series, which we will call A (Fig. 134); when the whole is melted, the surface of the metal is carefully skimmed and the fire withdrawn; as the cooling proceeds, the liquid lead is stirred with an iron spatula, and, like a saturated solution of common salt under similar circumstances, crystals soon begin to form, which sink to the bottom of the pan, and are taken out with a perforated ladle, that collects the solid particles of lead, and permits the fluid to run back again into the iron pan. As the crystals are taken out they are placed in the empty pan to the right hand side until about four-fifths, four tons, have been taken out, when the remaining fluid portion, or one ton, is ladled into the empty pot to the left of the workman; and the same operation repeated on five tons more *original* lead in the pot first used. It is evident that three pots, with the extra small pot C (Fig. 134) containing lead always heated for the purpose of keeping the ladle at the right temperature, so that the lead shall not solidify in it and stop up the holes at the bottom, would be sufficient to carry out the principle, but a great saving of silver and time is effected by arranging more pans right and left, so that the pure lead which crystallizes out is continually passing to the right, whilst the rich argentiferous lead is carried to the left. In every pan, when full, the lead is crystallized again, so that by the time it reaches the last pot to the right a mere trace of silver is left in the lead, which is cast into *pigs*. The enriched lead, called *lead riches*, passes from the last left-hand pot when it contains three hundred ounces of silver to the ton of lead, and is cast into bars about two inches square.

The last portion of lead is removed from the silver by melting and oxidizing the mixed metals upon a peculiar shaped vessel, of which the frame or skeleton consists of iron, and on this is worked a superstructure of bone earth or burnt bones, mixed with a certain proportion of fern

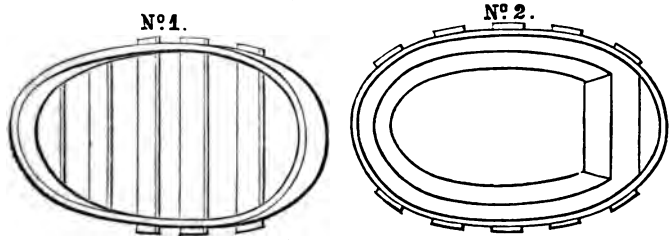


Fig. 135. No. 1. The iron rame of the test. No. 2. The iron frame rammed hard with damp bone-earth and dried, called the test or cupel.

ashes, and called a *test* or *cupel*, and having very much the shape of a meat dish. (Fig. 135.)

The test is placed in a furnace of a peculiar construction, so that the heated air and flame pass over it and up the chimney; and, in the first place, the heat must be most carefully applied, or else the test will be cracked and spoilt. When the *test* is sufficiently hot, the *lead riches* are melted in a side furnace, and poured into it. At first, the surface appears to be covered with dross, but in a short time it clears off, and the surface of the melted lead increases, and a film of melted litharge appears, which sinks into the test as if into a sponge; but when this is full, then a draught of air is directed over the surface of the argentiferous lead, and as the *test* is kept constantly filled with *lead riches*, the litharge or oxide of lead flows over the hollow part of the test, and is collected in a pot beneath. If the cupellation is conducted in one *test* to the end, directly the last portion of lead is oxidized and removed, the whole surface of the metal in the *test* suddenly brightens up and looks exceedingly beautiful; and if the silver is allowed to cool, another curious phenomenon is exhibited, called *spitting*, by which a quantity of oxygen gas dissolved in the fluid silver, like the solution of any gas in water, is suddenly discharged, producing those irregularities on the surface of the silver which very much resemble exhausted craters of extinct volcanoes. It may be prevented by throwing charcoal powder on the melted silver. At the Great Exhibition in Hyde Park masses of silver presenting the appearance just described were exhibited, one of which weighed 7703 ounces troy, and another, exhibited by Mr. Sopwith, weighed 12,162 ounces. Having thus briefly described the processes by which silver is obtained from its ores, we may now pass to the chemistry and technical applications of the metal.

Experiments with Silver.

First Series.

Pure silver has a specific gravity of 10·47, and its equivalent or combining proportion is 108·1; its malleability and ductility are next to those of gold; silver leaves have been beaten out as thin as the ten-thousandth part of an inch, and five grains of silver may be drawn out into a wire two thousand feet long. It is separated from all common metals with which it is likely to be associated, except gold and platinum, by the process of cupellation called the assay of silver by the "dry method." The method of separating lead from silver on a large scale has already been explained in connexion with Pattinson's process; but in order to conduct an assay, little cups of bone earth must be constructed by forcing it, while slightly damped, into a proper mould. The form and mode of making these cupels are as well illustrated in the

work of Pettus as in the modern works on metallurgy; and, indeed, the use of the cupel, or copel, appears to be very ancient.

Fig. 136. "1 and 3. Copel moulds or cases. 2 and 4. The copels that are made in them. 5. The copels as they are set upon one another. 6. The washed bone-ashes or char made into balls. 7. He that works the ashes. 8. He that strikes the copels into their moulds or cases." (Pettus.)

When the cupels are dry, they are heated by being placed in a sort of earthenware oven, with slits or openings in it at the sides, and called a muffle; this latter is supported in a furnace, so that the open mouth of the muffle corresponds with that of the furnace. The various forms of the muffles and portable furnaces are likewise well illustrated by Pettus, and leave little to be desired.

The fuel is put on at the top and lower opening, and the muffle is supported on iron bars above, so that the mouths of the muffle and

furnace are one. After the cupel is sufficiently heated, the lead containing silver is placed into it, and the heat being urged for a few

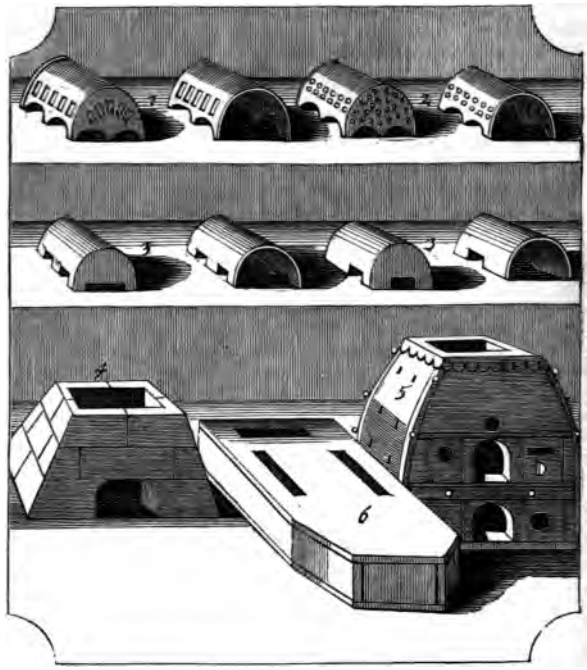


Fig. 137. "Nos. 1, 2, 3. Different forms of muffles. No. 4. An assay oven made of tiles joyned together, which may quickly be done. No. 5. An assay oven made of armour plate. No. 6. The foot of it." (Pettus.)

minutes, the lead soon melts, the dross on its surface flows off, and sinks into the cupel, and the metal is *uncovered;* when that takes place, the heat must be regulated, and the oxide of lead or litharge is soon absorbed into the cupel, and the *brightening* of the little speck of silver at the termination of the process demonstrates when it is complete. A great many precautions are necessary in conducting the assay. The muffle must neither be too hot or too cool: in the one case the silver is carried off and lost by sublimation and absorption into the cupel; and in the other, the absorption of the litharge into the cupel does not go on

properly, the little speck or button of silver is not properly refined, and contains a certain amount of lead. The mouth of the cupel must be closed or half closed or opened during the process, according to circumstances, and convenient tongs are supplied for the purpose of putting in or taking out the cupels. At one of the meetings of the Chemical Society Mr. Taylor made the following interesting observations on a new form of muffle and a simple mode of cupelling, which appears to be well adapted to amateurs and others who do not wish to incur the expense of building a muffle furnace, such as that depicted in the next cuts :—

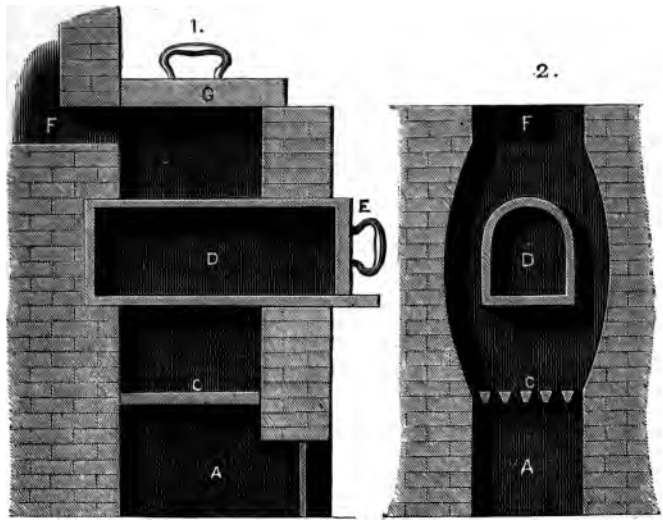


Fig. 138. Nos. 1 and 2, cupelling or enamelling furnace. In both A is the ash-pit, C the fire-bars, D the muffle, E the opening for introducing the muffle, F the chimney, and G the cover.

"Cupellation is an operation not often performed by amateurs, chiefly on account of the difficulty in doing it, unless provided with furnaces built expressly for the purpose. The following plan affords the most accurate results, while it may be performed in any furnace. The mouths of two black-lead crucibles of the same size are to be ground flat, so that, when applied one to the other, they may stand quite steady. An oblong or semicircular notch is to be cut out of the mouth of one of the crucibles, and a hole is also to be drilled through its bottom. This

crucible, when placed upon the top of the other, constitutes the muffle, and of course resembles in shape a skittle. To cupel with this apparatus, the lower crucible is nearly filled with clean sand, set upon the bars of the grate in the centre of the furnace, and brought to a low red heat. The cupel containing the lead and the alloy is then placed upon the sand, and immediately covered by the other crucible, taking care that the notch in its side shall be opposite to and correspond with the furnace door; more fuel is added, during which it is well to cover the hole in the top of the muffle with a crucible lid, in order to prevent the admission of dirt. When the muffle has become throughout of a bright red heat, the furnace door is thrown open, and the ignited fuel gently moved aside, so as to permit a view of the side opening in the muffle. The current of air which is thus established through the muffle instantly causes rapid oxidation of the lead; and this may be regulated at pleasure by closing the door more or less. If, from the fuel falling down, any difficulty should be experienced in maintaining a free passage of air, a portion of a porcelain tube or a gun-barrel may be passed through the furnace door to within an inch of the muffle; but this proceeding is generally rendered quite unnecessary by taking care to place some large pieces of coke immediately around the door of the furnace. In many cases it will be found advantageous to convert the lower crucible itself into the cupel by first half filling it with sand, and then ramming in pounded bone earth. I have found the above method to possess the following advantages. In the first place, the crucible may be maintained at a much higher temperature than can be readily obtained when the ordinary muffle is used, while the degree of heat and the quantity of air admitted may be regulated with the greatest nicety. Secondly, owing to the greater draught of air, the oxidation of the lead is more quickly effected; and, lastly, by looking through an opening in the furnace-cover, the operation may be watched from first to last."

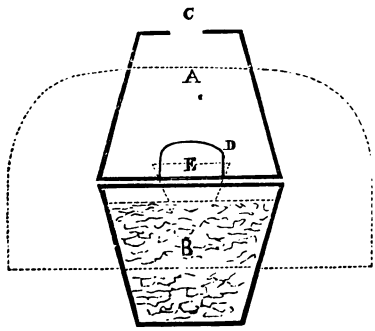


Fig. 139. A B. Black-lead crucible. C. The upper opening. D. The lower opening. E. The cupel. The dotted semicircle represents the position of the furnace door.

Second Series.

Silver is separated from gold and platinum by dissolving it in nitric acid, which does not attack either of the other metals; the solution of nitrate of silver, after careful filtration, is precipitated with one of

chloride of sodium, and the chloride of silver is thoroughly washed with boiling water, dried, and mixed with black resin in the proportion of three parts chloride of silver to one part resin; a gentle heat is applied at first, when the hydrogen of the resin unites with the chlorine of the chloride of silver, and a green flame is produced from the hydrochloric acid formed by their union. The heat of the furnace is gradually increased so as to afford a temperature of 1223° (Daniell's pyrometer) the melting point of silver, and after tapping the crucible to shake down the finely-divided silver, and adding some borax, a button of pure silver is obtained, after the crucible is taken out, cooled, and broken.

Third Series.

Chloride of silver, when fused in a little porcelain cup, or allowed to cool, forms a tough, hard substance, called by the old alchemists "*horn silver.*" This hard substance is difficult to remove from the porcelain vessel, but may at any time be decomposed and reduced to the metallic state by placing it in contact with some fragments of zinc and a few drops of sulphuric acid, when a beautiful arborescent formation of silver occurs, the particles interlacing with each other in the most curious manner. If the chloride of silver has not been fused, the decomposition by zinc occurs much more rapidly; and indeed this simple process should be borne in mind by all photographers who use large quantities of nitrate of silver. When the plates are placed on the developing stand, all the excess of the solution of nitrate of silver with the acetic acid and other matters should be allowed to run into a stone jar containing fragments of zinc; and at leisure times the metallic silver may be collected, digested with some dilute sulphuric acid, washed and dried in the oven, and will go a considerable way towards the purchase of fresh nitrate of silver.

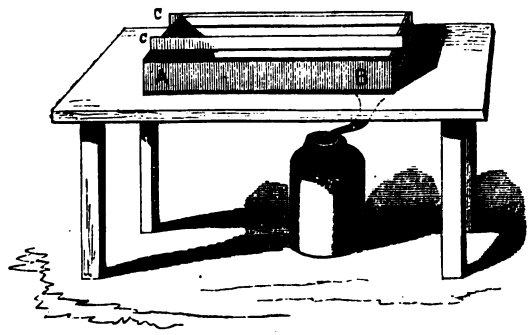


Fig. 140. A B. The gutta-percha trough and pipe leading to the stone jar containing zinc. C, C. Two glass plates levelled on the top of the trough, to carry the glass plates for developing.

Fourth Series.

Silver is easily dissolved by dilute or strong nitric acid. Boiling strong hydrochloric acid very slowly attacks finely-divided silver, which it converts into chloride; the latter is partly dissolved, and is precipitated again on the addition of water. Concentrated boiling sulphuric acid oxidizes and dissolves silver, and is sometimes used in the arts for the purpose of conferring a peculiar surface on the silver called oxidized silver; the same result, however, is much more rapidly and expeditiously brought about by the agency of the voltaic battery.

Fifth Series.

There are three oxides of silver—

	Symb.	Eq.
The suboxide of silver	Ag_2O	= 224·2
The oxide of silver	AgO	= 116·1
The binoxide of siver	AgO_2	= 124·1

The most important and useful of the three oxides is the oxide of silver, AgO, which is easily prepared by the mixture of hot solutions of nitrate of silver and caustic potash, until the latter is shown to be slightly in excess on testing with turmeric paper. The precipitate is then well washed with boiling water, and when dried at 140° Fah., is a dark-brown powder, containing one equivalent of silver and one of oxygen.

Sixth Series.

When a solution of nitrate of silver is precipitated by one of potash, and the moist and recently prepared oxide digested with a little ammonia for some hours, there remains a dark-black powder, and a considerable proportion of the oxide of silver is dissolved. The black powder may be placed in very minute quantities on separate pieces of blotting-paper, and dried, and is, in fact, that most dangerous compound of silver called fulminating silver, and supposed to be a nitride of silver consisting of three equivalents of metal to one of nitrogen. The author does not recommend the manufacture of these dangerous fulminating compounds, and has only described the mode of making the fulminating silver because amateurs, when making experiments in photography, sometimes put together very odd mixtures, and unwittingly prepare fulminating silver, which, exploding when wholly unexpected, produces the most lamentable results. Crackers, which the police object to so much on the Derby Day, are sometimes made with this compound.

Seventh Series.

Silver remains perfectly bright in an atmosphere which is quite free from sulphuretted hydrogen; consequently, silver plate is kept clean longer in the country than in London. Silver ornaments, such as silver girdles and tassels, retain their brilliancy for any length of time if placed in a clean, dry, and well-stoppered bottle. The ordinary black-

ness or film of sulphide of silver is soon removed from silver plate by a little solution of cyanide of potassium, which, in conjunction with whiting, is an excellent mixture for cleaning silver plate, and much better than the mercurialized chalk or ordinary plate powder. The bottle containing the cyanide of potassium should be labelled "poison."

Eighth Series.

Ordinary marking ink is prepared by dissolving two drachms of fused nitrate of silver in six drachms of distilled water, and then adding to the solution of nitrate of silver two fluid drachms of thick mucilage of gum arabic. The linen or other fabric is prepared with a mordant composed of a solution of half an ounce of washing soda (carbonate of soda) in four ounces of water, and half a fluid ounce of thick mucilage of gum arabic, called the preparation. Writing with the marking ink is rendered more legible by the addition of a little finely-powdered charcoal or Indian ink; and to form a distinct writing upon cloth, it is necessary to carry all the strokes of the pen downwards, and the pen should have a short and stiff nib.

Ninth Series.

Silver is obtained in the metallic state from the chloride by processes already explained at p. 225. The silver tree, or Arbor Dianæ, so called, was originally devised by Lemery, and the following is his process: Dissolve one part of silver in dilute nitric acid. Dilute the solution further with twenty times its volume of distilled water, and add to it two measures of mercury. In about forty days the arborescent precipitate takes place. Homberg recommends the preparation of an amalgam of four parts of silver and ten of mercury, which is to be dissolved in nitric acid, and diluted with water equal to thirty-two times the weight of the metal employed; a lump of the same amalgam is then to be placed in the bottle, when the precipitation of silver very rapidly commences, and assumes the arborescent form. The same effect is produced by putting a soft amalgam of silver into six parts of a solution of nitrate of silver mixed with four of a solution of mercury. When these precipitations are conducted in one of the glass globes used by engravers for concentrating light upon their work, the effect of the arborescence is very

Fig. 141. Engraver's Globe, with Arborescent Precipitate of Silver. The globe, of course, must be entirely filled with the solution.

pretty. In this experiment a voltaic action is set up, the acid and oxygen passing to the mercury, whilst the hydrogen travels to the silver, deoxidizes, and gradually precipitates it in the metallic state. A polished strip of ivory soaked in a dilute solution of nitrate of silver until it acquires a yellow colour, and then taken out and immersed in a tumbler of distilled water, whilst exposed to the action of the sun's rays, turns black in the course of two or three days. If taken out, dried, and rubbed, the black surface soon changes to a bright one of metallic silver. A stick of clean phosphorus immersed in a solution of nitrate of silver is gradually covered with fine dendritic or arborescent crystals of metallic silver; the phosphorus deoxidizes the solution. Mr. John Spiller, of the War Department, Woolwich Laboratory, has made some important experiments on the composition of the film deposited by the action of light and deoxidizing agents on the surface of glass and paper used for photographic purposes.

Tenth Series.

Silver unites with chlorine, iodine, bromine, and fluorine, forming the chloride, bromide, iodide, and fluoride of silver. The chloride is easily prepared by the addition of a solution of common salt, or some dilute hydrochloric acid to a solution of nitrate of silver. A white curdy precipitate is thrown down, which must be allowed to settle, and may then be washed by repeated decantation. It always settles better after the addition of some nitric acid.

In the "Boy's Playbook of Science" the use of chloride of silver, in the preparation of "photogenic" or copying paper, has been described in the article on photography. Light changes the white chloride of silver to a violet, which finally becomes black. This change occurs much more rapidly in the presence of organic matter. Chloride of silver is completely insoluble in water and in nitric acid; boiling strong hydrochloric acid will dissolve a small portion, which it deposits in minute octohedral crystals when carefully evaporated. The addition of water to the latter solution likewise causes a precipitate of the chloride of silver. Boiling-hot solutions of caustic potash and soda decompose, whilst cold dilute solutions have no effect upon the chloride. A solution of ammonia, however, rapidly dissolves it.

The chloride of silver has the curious property of absorbing one equivalent and a half of dry ammoniacal gas; heat is evolved, and, when saturated, the chloride gives up the ammonia rapidly on the application of a gentle heat, such as that of the hand; and if a thermometer is surrounded with it, the fall in the temperature is very apparent. The chloride of silver saturated with dry ammoniacal gas may be employed to illustrate the liquefaction of the latter gas, by placing some of the compound in a bent tough glass tube hermetically sealed; on gently heating the extremity where the chloride is placed, and surrounding the other end with ice, the ammonia is driven off and liquefied. When the heat is withdrawn, the gas is again absorbed by the chloride of silver, which rises to a temperature of 100° Fah. during the absorption and

condensation of the ammoniacal gas. Chloride of silver dissolves quickly in solutions of hyposulphite of soda and cyanide of potas-

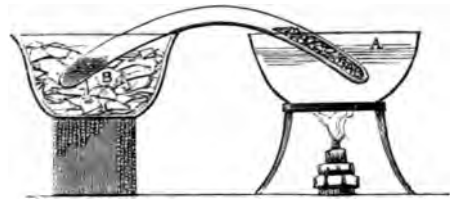


Fig. 142. The Liquefaction of Ammoniacal Gas. A. Extremity of the bent-glass tube containing the chloride of silver saturated with dry ammoniacal gas, and placed in a copper pan containing water, and gently heated by the spirit-lamp below. B. The other end of the tube surrounded with ice, where the liquefaction of the gas takes place by its own pressure and the cold.

sium, and forms a cyanide which may be employed for silvering; it also dissolves in a solution of chloride of sodium and in other chlorides, forming double compounds. The presence of nitric acid appears to prevent their formation, and hence the addition of nitric acid after the precipitation of the chloride with nitrate of silver. At a temperature of 500° Fah. the chloride fuses, and when cold, solidifies into a tough mass somewhat like horn; and hence its ancient name of "horn silver."

The reduction of chloride of silver to the metallic state has already been explained in the third experiment, p. 225. A solution of nitrate of silver is precipitated by one of bromide of potassium, forming the bromide of silver (AgBr). It very much resembles the chloride, from which it may be distinguished by its lesser solubility in ammonia, also by the disengagement of bromine vapour when heated in an atmosphere of chlorine, which of course has no action upon the chloride of silver.

When crystals of iodide of potassium are added to a solution of nitrate of silver, the iodide of silver (AgI) is produced of a yellow colour, and soluble in an excess of iodide of potassium; it is usual to add the crystals of iodide of potassium to the nitrate of silver until the yellow precipitate formed is redissolved. This solution precipitates iodide of silver when diluted with water, and is used in the preparation of Talbot's iodized paper, or rather iodide of silver paper, which is first wetted with it, and then dipped in water; the latter causes the precipitation of the iodide of silver on the surface of the paper by the dilution of the concentrated solution of iodide of potassium.

Iodide of silver is almost insoluble in ammonia, and is readily distinguished from the chloride by its colour, its permanence in the presence of light, and the violet fumes of iodine it evolves when decomposed by chlorine gas.

Eleventh Series.

Electro-silvering may be conducted precisely in the same manner as the gilding processes described in experiments pp. 204-5, substituting, of course, silver for the gold leaf or foil. On the small scale, a silvering solution is rapidly prepared by dissolving a threepenny piece in a little nitric acid contained in a test tube: the solution is poured into a mug containing some dilute hydrochloric acid or solution of salt, and, after being allowed to settle, the precipitated chloride is washed several times with boiling water. The moist chloride of silver is then dissolved in a solution of cyanide of potassium, and placed in a small

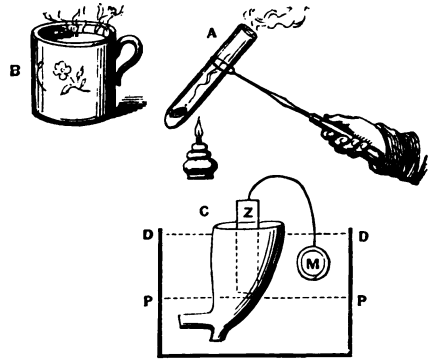


Fig. 143. A. The test tube containing the threepenny piece and nitric acid. B. Mug containing boiling water with a small quantity of hydrochloric acid. C. The gallipot with bowl of tobacco-pipe set upright in plaster of Paris (P P), and containing the dilute sulphuric acid and zinc (Z). D D. Solution of silver surrounding the bowl of the tobacco-pipe, and containing the article to be silvered (M).

gallipot containing the bowl of a tobacco-pipe fixed in with plaster of Paris, so that the latter completely stops the little tube or opening communicating with the stem, and at the same time keeps it upright. The bowl of the pipe may contain water mixed with three or four drops of sulphuric acid, and a bit of amalgamated zinc being placed therein and attached to a wire connected with a clean copper or brass article, it is instantaneously silvered when immersed in the solution of the chloride of silver in cyanide of potassium.

Twelfth Series.

Silver is easily removed from worn or injured plated goods by the following solution: Oil of vitriol, together with five per cent. of nitrate of soda, is heated in a cast-iron boiler, or, better, a stoneware pan, to 212° Fah. The silver-plated article, after being carefully freed from grease by immersion in a boiling solution of carbonate of soda, is then attached to an iron wire and held in the acid solution until the silver is removed; it may then be taken out and well washed under a tap of water.

Thirteenth Series.

Mr. Thomas's Formula for the Preparation of the Nitrate of Silver Bath for Collodion Plates.—Into a 20-oz. stoppered bottle put nitrate of silver 1½ ounces, distilled water, 4 ounces—dissolve. To this solution add iodide of potassium, 4 grains, dissolved in 1 drachm of distilled water. Mix these two solutions; the precipitate (iodide of silver) thus formed is, by shaking, entirely dissolved. Add 16 ounces of distilled water, when the excess of iodide of silver is again thrown down, but in such a finely divided state as to render the saturation of the bath with iodide of silver perfect. Now drop in sufficient of the oxide of silver to turn the turbid yellow solution a dirty brown colour; so long as this effect is produced, the quantity of oxide of silver, however much in excess, is of no consequence; shake the bottle well for 10 minutes or so at intervals, then add alcohol, 30 minims, and filter; to the filtered solution add dilute nitric acid of the strength stated, 5 minims. The bath is now ready for use, and should be quite neutral.

Fourteenth Series.

Silver is detected by the following tests: Solutions of silver are precipitated by hydrochloric acid, forming the chloride of silver, which blackens by exposure to light, especially when mixed with a little gallic acid. The chloride is soluble in ammonia, and is reduced by zinc to the metallic state. The precipitated silver may be collected, washed with dilute sulphuric acid, and finally with boiling water; collected, dried, and fused by the blowpipe with borax into a little button of silver. The little button of silver may be dissolved in nitric acid, and portions of the solution tested on slips of glass with hydrochloric acid and ammonia. Sulphuretted hydrogen or a solution of hydrosulphuret of ammonia precipitates the black sulphuret of silver insoluble in dilute acids, alkalies, alkaline sulphurets, and cyanide of potassium. A solution of iodide of potassium precipitates the yellow iodide of silver soluble in excess of concentrated solution of iodide of potassium. Potash and ammonia precipitate the oxide of silver soluble in the latter, but insoluble in the former. It will be evident that solutions of hydrochloric acid and ammonia afford the most characteristic results with

solutions containing the metal silver; and although the chlorides of lead and mercury are precipitated by hydrochloric acid, they are readily distinguished from silver by other tests explained in the respective chapters on these metals.

Fig. 144. Elaborate Work of Art in Silver, by Hunt and Roskell; the lid is removed when the vase is to contain flowers.

Fig. 145. The Planet Saturn.

CHAPTER VI.

LEAD. ♄

The character is supposed to represent the scythe of Saturn, "Old Time."

We are reminded by the cut at the head of this chapter that Saturn was the ancient name given by the old alchemists to this element, and as the properties of the metals known to the ancients will first engage our attention, we may proceed with the enumeration of those belonging to lead, because it is so intimately connected, in its natural or mineralized state, with the noble metal, silver.

Lead has been known from the most ancient times, both in the metallic and combined state. Ever since the time of Moses (and how long a time before that period it is difficult to say) lead has been in use, and has continued in use from that time till the present day. It is stated that the Romans sheathed the bottoms of their ships with lead, and fastened it on with bronze nails, whilst the Roman ladies, like some silly females of our own day, used the carbonate of lead, or white-lead, for a cosmetic. The use of "face powders" is fortunately rather the exception than the rule, sensible people being generally content to wash

their faces; and young persons cannot be too careful in avoiding the use of such things, as they sometimes cause paralysis, and the countenance is distorted by the involuntary twitching of the facial muscles. The oxides of lead are used as pigments, and also in the manufacture of the finest glass. The acetate, or sugar of lead, is likewise employed for various useful purposes, and especially in dyeing and the preparation of certain pigments. Lead has not only a bad reputation for producing "the plumber's colic," when gradually absorbed into the system, but its poisonous qualities have been unwittingly demonstrated by those unfortunate persons who have swallowed wine sweetened with poisonous acetate of lead (formerly much used by wine merchants for preserving wines from acidity), or by children who have partaken of "lollypops" coloured with red-lead, or eaten "Bath buns," as Dr. Griffin of Bristol has proved, rendered more fatal by sulphide of arsenic, mistaken for chromate of lead or chrome yellow. The alloys of lead are very important, and their composition is stated in the experiments with this metal.

Nearly all the lead of commerce is obtained from a mineral called "galena," or "lead-glance," being a sulphuret of lead (PbS), and diffused through (more or less) vein-stone or "*gangue*," a word derived from the German *gang*, a vein. When pure, every 100 parts of galena are composed of lead 86·55, sulphur 13·45.

In the chapter on coal it has been explained that, by the disturbance of the original layers or strata of rock and coal, they are brought nearer the surface of the earth, and are discovered in positions they would not otherwise have held. The same observation applies to minerals such as lead ore, which has undoubtedly been deposited in the metamorphic rocks, such as clay-slate, quartz rock, &c., and therefore very low in the order of deposition; but the same convulsions of nature which have thrown up the coal have performed a similar benevolent office for the useful minerals, which are thus brought within the reach of the industrious hands of man. When the geological survey of a country leads to the supposition that minerals are present, the miner does not speak of "*boring*" and "*winning*," as he would do if he were searching for coal, but uses other terms, such as "*exploring*," "*shoading*," and "*costeaning*," and he terms the rock in which the mineral is deposited the "*country*," whilst the mineral itself is distinguished as the "*lode*." In a mountainous or hilly region, a "lode" or metallic vein may "out-crop" or come to the surface of the earth; but then centuries will probably have elapsed since the event occurred, and by the time the country is explored, great changes of the surface will have been brought about, so that, by the action of water, particles of the lode will be carried a great distance from the locality to which they originally belonged, and the lode itself be completely hidden by the alluvial cover. The Cornish miners have always been celebrated as keen observers of nature, and, like the Red Indians of America, can take up and follow a "mineral trail" with the most unerring precision. When they endeavour to trace the mineral particles discoverable in the lower levels to their source, it is called "*shoading*," and the water-worn and rounded bit of mineral is termed

a shoad-stone. "*Costeaning*" is analogous to the "*boring*" for coal; and a number of pits, like churchyard graves, are sunk in places where the

Fig. 146. Section of Hill containing the Mineral Lode A B. The figures below are supposed to represent the miners "*shoading*" and tracking the shoad stones from the bed of the river flowing at the base of the hill to their source at the "*broil*," or head of the vein at A. It is seldom that a mine is opened from the surface or *grass*.

mineral is supposed to exist. The holes or pits are sunk near each other, and at right angles, or nearly so, to the supposed direction of the lode, and in order that no mineral may escape discovery, the pits are connected together by "cross-cuts" below. The science of geology no doubt is of great value in preventing foolish schemes for mining districts where no minerals exist; but it is evident that nature is continually at variance with scientific prognostications, or else the shares of mines would not fluctuate so fearfully in the market. Any man who could examine and determine the probable mineral riches of a mine would make a rapid fortune by speculating in shares; but this kind of knowledge has never yet proved infallible, and, like the diagnosis and prognosis of the physician, is frequently right, but very often wrong, because the human body, and the rocks, happen to be both opaque and return no direct answer to the prying eyes of the observer. In a mining district every well sunk or hole dug is examined with the sharpest scrutiny; and when minerals are discovered, the next thing to be done is to drive an adit or horizontal entrance into the rocks, provided the conformation of the country admits of it. The adit level has already been described in the article on coal at p. 52, for the purpose of showing the most simple method of draining a mine, and is repeated here in another picture taken from George Agricola's practical work on mining, which is probably one of the most complete books ever written on the subject; and when it is considered that the work is more than three hundred years old, the reader will marvel at the careful practical observations of the ancient miners, and how little they allowed to escape them. This old book contains nearly everything, except the use of the

steam-engine, that might be found in a modern treatise on mining operations.

Fig. 147. The Adit Level. A, A. Two uprights or yokes supporting a bearer B B. C. The well, pit, or shaft. D. First cord. E. Weight of the first cord. F. The second cord, fixed to the earth at G. H. Head or ends of cords. I I. The mouth or entrance of the adit or tunnel. K. The third cord, with weight attached. L. M. The first measure; N, the second; O, the third, forming the triangle F. (Agricola.)

In the above cut the miner, or the person corresponding with the modern superintendent or captain, is making out the course along which the tunnel or adit is to be driven in order to meet the shaft. At the present day, great credit is due to the captains, who, by carefully dialling the ground with the assistance of a theodolite mounted over an ordinary mariner's compass, direct the underground work of the miners with the greatest precision, so that they may even excavate the different portions

of a shaft independently, one under the other, which shall form a perpendicular pit when united together.

During a leisure month the author visited the famous Tamar lead-silver mine near Beer Ferrers, on the banks of the river Tamar in Devonshire; and having an introduction to the "captain" of the mine, was enabled by his courtesy to see the whole of these interesting works. Like the labourers in the coal pits, every class of persons engaged has its peculiar title, which appears, in mineral mines, to be in some degree borrowed from the sailors, as the head business man is styled the "*purser*," and under him is the agent called "*captain*," who likewise has subordinates, termed "*underground*" and "*grass*" *captains;* the latter superintends the preparation, cleaning, or *dressing* of the ore, and the other works on the surface; the former looks after the pumps and attends to the timbering of the chambers, galleries, shafts, and the general works underground. The miners are classed in two great divisions, viz., the *underground* and *surface* men. The underground miners are subdivided into *tutmen* and *tributers*. The former, as it were, cut the underground road by sinking the shafts and excavating the adits and galleries, and the latter, using the path dug out by the *tutmen*, undertake to find and bring the ore to the surface. The *tributers* are speculators or adventurers, and the greater part of the money they earn, except the *sist money*, is derived from a per-centage on the value of the ore after it is prepared for market; and as this may vary, according to the mineral, from 6*d*. to 13*s*. 4*d*. in the pound, the fascination of this game of chance is very great. The *surface* men attend to the water- or steam-engines, and also to the different kinds of machinery used in dressing the ore for market; and whether *surface* or *underground* men, their lives are passed in a continual round of hard labour. The number of persons employed in the mining districts of Devonshire and Cornwall has been estimated at about 30,000.

Having been duly equipped in miner's costume—a flannel shirt and trousers, worn close to the skin, in order to afford a porous medium for the escape of the perspiration, a pair of thick shoes, a linen cap, and a stout broad-brimmed hat with a lump of clay in front to hold the lighted candle—the visitor starts on his dismal route. The bustle and excitement which prevail at the mouth of a coal pit are not observed at the brink of a mineral one. The traveller commences his weary journey at once by clinging to the ladder and slowly descending, taking rest occasionally upon the stages which occur about every three fathoms, and probably thinking of the hard work he will have to go through before he reaches the summit again and once more breathes fresh air; indeed, the downward journey must not be attempted unless the visitor is sure of his physical powers being equal to the exertion required. Nothing can be more dismal or melancholy than the inside of a mineral mine. Writers of fiction may indulge in dreams of glittering ores bestudded with flashing jewels only waiting to be grasped by the avaricious hands of man, but stern reality is directly opposed to these poetical fancies; and although occasionally a great mass of glittering galena, or sulphuret of

lead, may suddenly reward the toil of the miner and cause the shares of the mine to give a spasmodic jump upwards, it rarely lasts, and perhaps is only the forerunner of a greater scarcity of the mineral. The visitor continues to descend through fathoms of rock, and the only noise he hears is caused by the up and down movement of the long rods of the pumping gear, or the occasionally scraping and grating of the buckets or *kibbles* containing the ore against the sides of the shaft. At last a

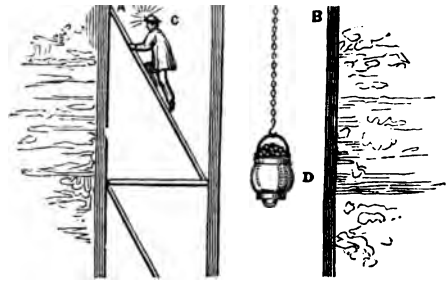


Fig. 148. Descent of a Mineral Mine. A B. A portion of the shaft, being a parallelogram about twelve feet by six, and divided in the centre; one division being for the use of the miner C, and the other for raising the ore in the iron basket or *kibble* D.

level is reached, and, with body bent, and in Indian file (for the levels are generally so narrow that they admit the passage of one person only at a time), the visitor almost starts when he comes suddenly upon a solitary miner digging out dirty-looking lumps of lead ore with bright shining speckles in them, which he is told is valuable, because it contains so many ounces of silver to the ton, and can by Pattinson's process be refined and the precious metal separated from the less valuable lead. The most brilliant and purest galena generally contains the least silver, and especially when it occurs in great bulk; but small forks, branches, and veins of galena ramified in a stratified rock, generally contain the most silver. A lead miner is glad to meet with galena in a limestone rock, because the vein is usually large; but his enthusiasm is checked when he discovers that it passes into sandstone, and especially when it enters shale or slate, for then it becomes a mere thread, or the ore disappears altogether. The mineral vein being reached, is usually found to slant or underlie to the right or left in the solid rock, passing downwards to a considerable depth. It is different from a seam of coal, which is one of the earth's strata, and can therefore be traced over a large area; whereas a mineral lode is a mere fissure or crack in the strata filled with a variety of mineral substances, such as carbonate of lime, or crystallized silica, or quartz, or fluor spar, and containing lead, tin, or copper, or other metallic ores. The probable riches of a coal field may be estimated with amazing accuracy, because it is an actual stratum of the earth, however disturbed it may have been since

its deposition; but there is no certainty with mineral veins, and what corresponds with the *fault* or *trouble* of the coal miner is exactly the locality that may contain the rich vein of the mineral seeker. The lodes usually take an easterly and westerly direction; but they are very capricious, and may vary in thickness from that of a sheet of paper to thirty feet.

The foreign matter or rubbish associated with the mineral ore is termed "*deads;*" and as the traveller passes down the beautiful river Tamar, or journeys in other parts of Devon and Cornwall, he may trace the progress of the underground work by the heaps of slaty poisonous rubbish thrown up in rugged heaps, looking as if it was a deserted railway embankment or other great engineering earthwork.

Having passed the solitary workman, the visitor will notice that a large quantity of timber is required to support the roofs, and his guide will probably tell him that under his feet there are two or three other similar galleries; and coming to a great hole, round which he creeps with some fear and trembling, he is informed that it is a "*winze,*" or perpendicular shaft, connecting the gallery through which he is walking, with the one below. The "*winze*" (Fig. 149) is intended to assist the ventilation of the mine, which is very imperfect and sluggish; so much so, that the poor miners are continually suffering from diseases of the lungs; and, although otherwise a strong, robust, and healthy class of men, they gradually succumb to the effects produced by inhaling the poison of their own breath mixed with the smoke and carbonic-acid gas from the candles they are obliged to burn in their gloomy and badly-ventilated mineral dungeons. The miners are quite aware of this state of things, and are paid much higher wages when they work in mines where the supply of air is known to be bad. It is a sad reflection on our law makers that they do not make the ventilation of mineral mines compulsory, and that they permit men, for the sake of a little extra wages, to take a slow poison that entails the penalty of consumption, which may be transmitted to their children. Experienced mining engineers are agreed that there is no reason why mineral mines of any importance should not be ventilated like coal pits. Mineral mines might, whilst worked in doubt or uncertainty, be allowed to escape the expense of ventilation; but directly a certain tonnage of ore has been extracted, then the owner ought to be compelled to give his miners air and ventilation like the coal-pit proprietors. It has been stated that the extra wages paid to miners who undergo the risks attendant upon breathing an atmosphere almost as bad as that of the Black Hole of Calcutta, would be amply sufficient to pay for the cost of ventilation. A mine is usually divided by the galleries and winzes into compartments about thirty-three feet long and sixty feet high, called "pitches," which are let by "Dutch auction" to the three or four miners for two months. Both the proprietor and workman are benefited by short leases, as there is no game of chance more uncertain than that of mining. A rich vein will suddenly melt away, not into thin air, but into profitless rubbish, having, as the Cornishmen call it, "taken a heave;" having, in fact, been displaced by some subterranean freak of nature, and either gone up or

down to delight the "*tributers*" and "*adventurers*" working other "*pitches*." Sometimes, when a lode is profitable, it "*takes horse*," being divided by another *lode* not of valuable mineral ore, but of "deads,"

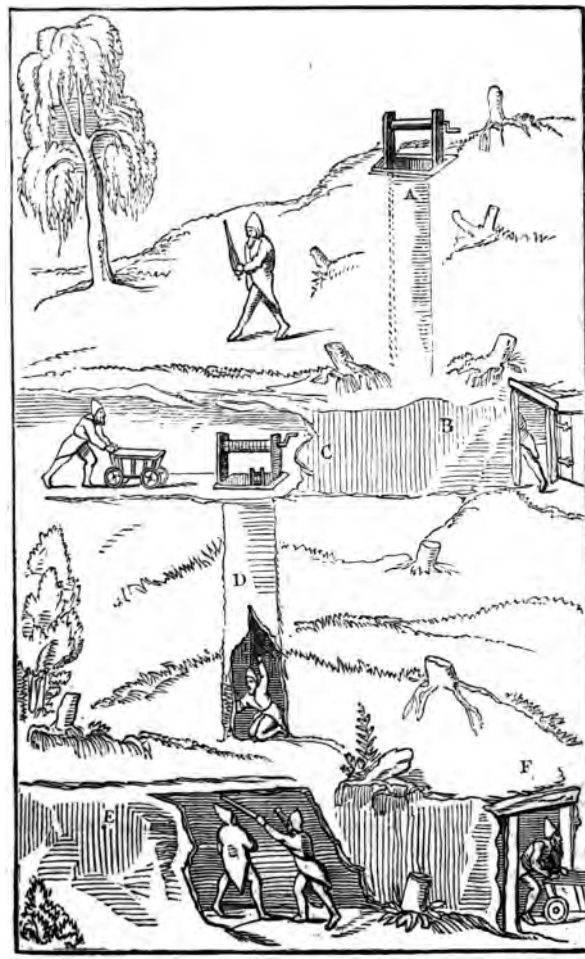


Fig. 149. A B. Main shaft. C E. Gallery heavily timbered. D. Shaft connecting the galleries with each other, called a winze. E F. Gallery timbered. (Agricola.)

such as clay slate, called "*fluckans*," which throws the lode out of its natural position, and gives the poor miners much harder work to secure. Should a miner become quite disheartened with his "pitch," he may resign it on payment of a fine of twenty shillings. Indeed, profit and loss seem to be equitably proportioned amongst masters and men; and the "strikes," which are so much to be deplored in certain coal districts, are hardly known amongst the intelligent hard working Cornish miners.

If the visitor is not already too much fatigued with his monotonous journey, he may continue slowly descending from gallery to gallery until he is informed that the river Tamar flows above his head, and that the surface of the water is about 220 fathoms distant from the place where he stands, or rather stoops. The miners actually penetrated to this depth below the water; and as the river was broad at that part, and they could not excavate air shafts, the works were abandoned for a time until they boldly commenced an inclined plane, beginning at a point about 100 yards below the top of the main shaft. This gallery was driven at an angle of 37° right through the old workings to a depth of 320 yards, and, at the suggestion of Dr. Spurgin, one of the most scientific and liberal-minded men at the Royal Polytechnic Board

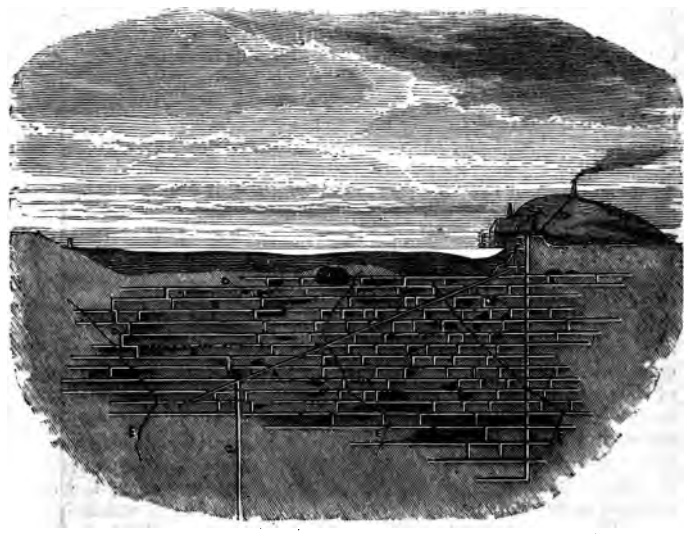


Fig. 150. Section of Tamar Lead Silver Mine, Beerferrers, Devon. A. Inclined plane, leading to workings and underground shaft. B. Entrance to inclined plane. C. The "Spurgin" shaft. D. The flue of the underground engine, two miles long. E. Slides in the ore.

of Direction, a twenty horse-power steam-engine was erected at the 145 fathom level, or 290 yards below the pit's mouth, which answered the purpose intended, viz., to pump water and raise the ore. The smoke from the engine was conveyed along a flue running through the old workings to the surface, and the shaft and engine were duly named after the learned and spirited gentleman who had proposed them. The visitor to the mines of Devon and Cornwall cannot fail to be struck with the absence of those engineering arrangements which are a matter of course at the coal mines of Newcastle and Durham.

Professor Hunt, the keeper of the Mining Records, informs us lead mining appears to have been carried on in this country from a very early period. When in the possession of the Romans, many of the lead mines in Wales and England were worked, and considerable quantities of lead obtained, as we may infer from the immense accumulation of slags in Derbyshire, the Mendip Hills, and elsewhere. There does not appear to have been any period in our history during which mining for lead was not followed to some extent; but in the reigns of Henry VIII. and of Queen Elizabeth, especially in the latter reign, a fresh impetus was given to British mining by the introduction of a number of German miners. That mining for lead must, previously to this, have been extensively carried out is proved by the circumstance that Edward the Black Prince took several hundreds of the Derbyshire miners into Devonshire, and it is said that the result of his mining speculations in the west was the realization of wealth sufficient to defray the expenses of his French wars.

If the amateur miner has experienced any fatigue during his progress, he must make up his mind to forget that such a fact has been forced upon his consideration; there is no friendly "corve" or empty coal basket to convey him quickly to *terra firma*, and he must now commence his laborious climbing upwards, which (if it does not bring on an attack of cramp at once) is pretty sure to be remembered when bed-time arrives, and the weary body is trying to sleep off the effects of a descent into the Tamar lead silver mine.

Having reached the surface or "grass," there is yet a great deal to examine, and the visitor will pass in the next place to that part of the works where the *sorting* and *cleansing* of the mineral ore take place, as the galena is rarely in a sufficiently pure condition to be taken at once to the roasting or smelting furnaces. After a considerable portion of the useless earthy matters are removed, either by "*hand dressing*" or by the help of sieves constructed of iron wire, it is then sometimes placed in other sieves and agitated in water, or it is washed like potatoes by placing the lead ore in large troughs full of water and stirring it with an iron shovel, called the *standing buddle* system; the latter method, however, is not so perfect as the *running buddle* which is used at the Tamar works, and involves the use of a more complicated arrangement of inclined planes with flowing water, so that the ore is sorted and cleansed in one complete series of operations. The similarity between the ancient and modern operations employed to prepare the ores for the

furnace, is again remarkably displayed in the curious work on the metals by George Agricola, published more than three hundred years ago.

Fig. 151. Old Method of sorting and cleansing Mineral Ores. (Agricola.)

In the above picture, the use of the various sieves and water for sorting and cleansing the ore is very clearly demonstrated, and the arrangements correspond precisely in principle with those employed at the present time. The next operation is the powdering of the ore, which is either done with a crushing machine worked by a steam-engine, such as that described and figured at p. 183, or by the more ancient arrangement of *stampers*, which correspond with the pestle and mortar used in every apothecary's shop for levigating small quantities of hard substances. In George Agricola's famous work, the application of different kinds of power, and especially water power, for working the stampers, and performing the numerous mechanical duties of mineral mines, is very carefully depicted and explained. In the next cut it is apparent that an overshot water-wheel gives motion to an axle, to which are attached cams; these strike upon the tongues fitted on the stampers or upright strong wooden beams, shod with masses of cast iron, and as these are alternately raised and allowed to fall they gradually crush the mineral. The stampers generally work in a large and stout wooden box, in which are openings fitted with gratings, and when the mineral is powdered sufficiently fine, the stream of water

allowed to enter the box gradually carries it through the perforations of the grating, and the powdered ore subsides or deposits in the pits or tanks connected with the stamping box.

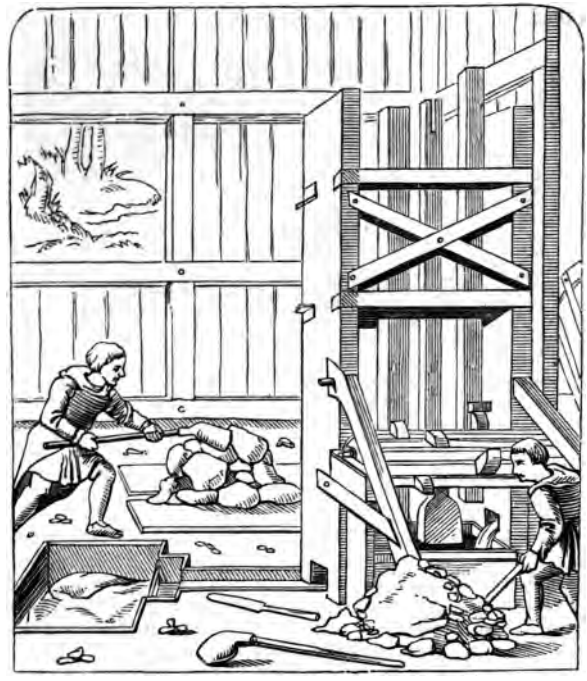


Fig. 152. Stampers and Box with Pits to receive the powdered Ore, used more than three hundred years ago. (Agricola.)

The main object of the stamper is to reduce the particles of the mineral to one uniform state of division, so as to prepare them for the succeeding operation of washing, performed with what is termed "*the nicking buddle*," which is a long wooden box or trough, provided with a shelf at the head, and gradually inclined towards the foot. The ore is agitated by wooden shovels and implements somewhat like road-scrapers, and as the water is constantly flowing through the box it gradually carries off the lighter earthy matters or gangue, and leaves the heavy mineral behind. By constant practice the Cornish boys manage the agitation so well that the nearly pure and heaviest mineral is deposited at the head of the box, in the next division is the mixture of ore

and some earthy matter, and the third contains the very fine and poorer particles, which are further searched and winnowed from the associated powdered rock by means of the "*rack*." The *nicking buddle* employed at the present time differs very slightly from that employed in olden times, as will be noticed by the next interesting cut.

Fig. 153. The "Nicking Buddle." (Agricola.)

The rack is (as its name implies) only a more searching arrangement for the detection of the fine particles of mineral ore, and is used by placing the ore on the shelf, to which water is then admitted, and by constant but steady agitation with a hoe and birch broom, the dirt and earthy dust are carried away, and the ore deposited on the floor of the rack or cradle. For the convenience of removing the ore from the floor of the "rack," the lower part is usually supported on an axis, by which the table is moved into an upright position, or, as may be noticed in George Agricola's picture (Fig. 154), it is simply rested against the wall, and the finely powdered ore washed off into a pit below, divided into one or more compartments corresponding with the divisions in the floor of the rack, so that the most valuable mineral at the head is separated from the lighter and less important mineral collected at the foot of the

rack; indeed, the whole of the washing operations conducted by the *nicking buddle* and *rack* are based on the principle of the different specific gravities of the pure and impure ore, the former being heavy, whilst the latter is several degrees lighter by admixture with earthy matters.

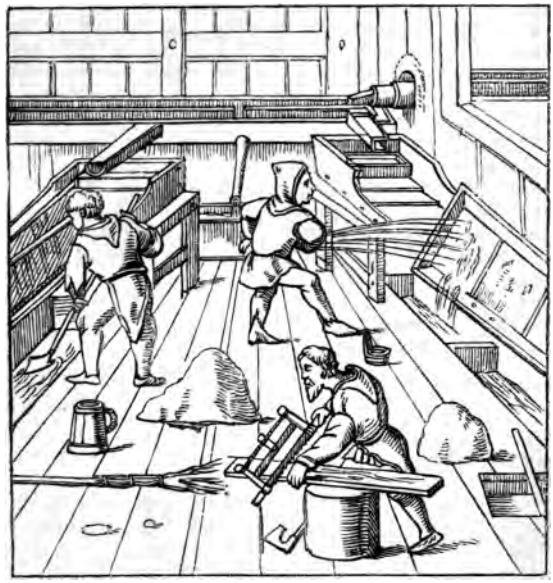


Fig. 154. "The Rack." (Agricola.)

After these mechanical operations are completed, the different qualities of powdered ores are mixed together according to the results obtained by a preliminary assay on the small scale, and being both roasted and smelted in a reverberatory furnace, the galena or sulphuret of lead is reduced to the metallic state.

The sulphur and lead which galena contains are in such proportions, that when both are united with oxygen and converted, the one into sulphuric acid and the other into yellow oxide of lead, the acid and oxide exactly saturate each other and form sulphate of lead (PbO,SO_3), hence the object of the preliminary roasting, which is managed by spreading the ore out equally on the hearth or bottom of the reverberatory furnace, and the latter being already red-hot, communicates its heat to the mineral, which is stirred about occasionally with an iron paddle in order that the air may have free access to the sulphuret, and convert it

into sulphate of lead. Several reverberatory lead furnaces usually communicate with one main chimney, and this being enlarged into various flues and chambers placed almost at right angles to each other, the lead fumes volatilized during the process are in a great measure saved and re-smelted. The loss of lead from volatilization is very considerable, amounting to ten per cent. or more. Accordingly flues of great length, sometimes exceeding a mile, are constructed in order to effect as completely as possible the condensation of the lead smoke or fume. Other contrivances with the same view have been adopted; the smoke has been caused to pass through water by means of powerful exhausting pumps, or water has been projected in a finely divided state, like rain, into chambers through which the smoke has been made to circulate; and other methods have also been tried with greater or less success, but all attended with no inconsiderable outlay. Mr. John Taylor, jun., has suggested a fundamental improvement in the smelting of lead ores, and recommended the endeavour to effect the object at a temperature lower than that required for the volatilization of the lead.

When the roasting has been continued for some time, the skimmings of the lead obtained from the previous batch of ore smelted are thrown into the furnace, and the whole well stirred together; and the lead obtained at this stage of the process is run off at once from the taphole B

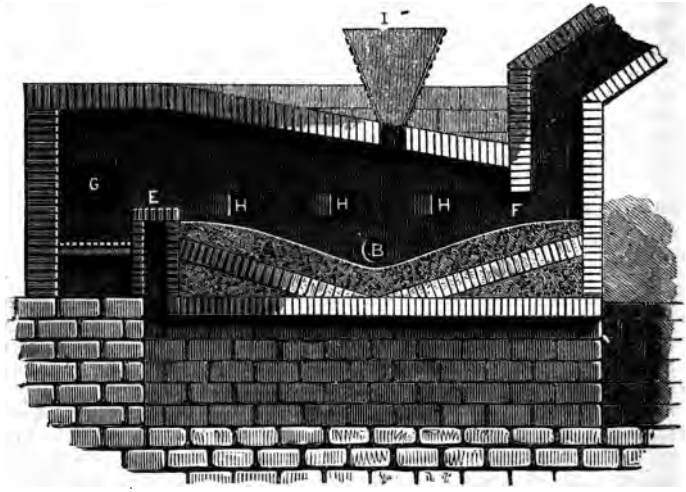


Fig. 155. Section of the Reverberatory Furnace used for roasting and smelting Galena. A. The hearth or sole of the furnace. B. Tap hole. E. The bridge which separates the fire from the hearth upon which the ore is placed. F. The flue. G. Hole through which the fuel is placed in the fire below. H, H, H. Openings, closed by sliding iron plates, for the admission of air. I. The hopper by which the ore is passed into the furnace.

(Fig. 155). The fire is now reduced, and some quicklime thrown upon the lead, the effect of which is to produce a silicate of lime, and it also sets free a portion of oxide of lead. The fire is again raised, the lead run off, and finally an excess of lime being added, the slags are then made sufficiently solid to be easily removed, and directly one batch is finished it is succeeded by another, so that the increased heat of the furnace in the last operation, serves to bring the cold lead ore of the next to the proper temperature required for the first operation of roasting.

The chemistry of the smelting process may be thus described:—Sulphide of lead or galena (PbS) is partly converted by roasting into sulphate of lead ($PbSO_2$), which, mixed with the undecomposed sulphide of lead (PbS), produces two proportions of metallic lead (2 Pb), and two proportions of sulphurous acid gas (2 SO_2).

The pigs of lead of course contain the silver, which may be separated by Pattinson's process, in the manner already described in the article Silver, p. 218.

Metallic lead has a bluish-white colour; and when recently cut, melted, or scraped, presents a brilliant lustre, which rapidly fades, as the metal, when exposed to the air, is converted into a suboxide of lead. The softness of lead renders it extremely useful in the shape of wire for horticultural purposes, whilst its well-known malleability enables it to be applied in sheets for covering the roofs of houses; in both these cases the length of time required to rust or oxidize lead renders these applications of the metal of extreme value. One of the most interesting modes of showing the softness of lead, is by placing a common seal of sealing wax between two pieces of soft lead on an anvil, and striking them suddenly with a tolerably heavy hammer, a correct impression of the seal on the lead is obtained, from which other sealing wax impressions may be taken, and it is said that this was the mode employed by inquisitive post-office authorities in olden times, when they wished to know the contents of a letter without betraying the fracture of the seal.

The specific gravity of lead is somewhat high, being 11·445; it is unelastic, not sonorous like many other metals, and the density appears to be reduced instead of increased by hammering. It melts at about 635° Fah., and when exposed to a red heat with free access of air, it smokes, sublimes, and affords a grey suboxide, which settles on any cold surface. The effect of water upon lead has been carefully studied, and it seems to be received as an axiom that *pure* water absolutely free from air will not attack pure lead; distilled water, otherwise pure, but containing a minute proportion of air in solution, gradually converts the surface of a sheet of clean lead partly into white spangles of hydrated oxide of lead. The presence of ammonia in distilled water is often overlooked, and, as shown by Medlock, is frequently the attacking agent. It has been found that certain waters containing salts in solution, and especially the sulphate of lime, do not dissolve lead, consequently it was thought that hard waters might be safely conducted through leaden pipes, whilst soft waters were considered dangerous

because they contain air in solution, which first oxidizes the lead and forms oxide of lead, and this combining with the carbonic acid gas which is always an ingredient of spring, river, and rain-waters, produces carbonate of lead, commonly termed white-lead, and under these circumstances oxide of lead is found to be dissolved by the water. The author recollects a very interesting case of lead-poisoning by water passing through leaden pipes, which occurred many years ago, before the action of water on lead was understood, and it came under the special notice of the late Mr. John Thomas Cooper. This gentleman was employed to visit an estate, for the purpose of ascertaining which of three different springs of water was best adapted to supply the family mansion. The softest water having been selected, it was duly conducted by leaden pipes to the house, and the members of the family were loud in their praises of the excellence of the choice, and nothing occurred to cause any inconvenience to them until their return to the country after the "London season," when nearly the whole of the inmates were seized with violent cramps and other symptoms, which the local medical men pronounced to be colic, and they recommended at once an analysis of the water. On examination, it was found to contain an abundance of lead in solution, and on taking up the pipe, they discovered several ounces of white lead deposited in the interior, and especially where the pipe had taken a bend or circuit through a valley. The action upon the lead no doubt had commenced directly it was laid down and brought into use, but as long as the family remained in their country house, the demand for this precious necessary of life was so abundant, that it never stayed long enough in contact with the lead to dissolve an appreciable quantity. When, however, the family removed to London, the water was in less demand, and moved more sluggishly through the pipes, so that a large quantity of white-lead was formed, and directly the consumption of the water increased, the poisonous white-lead was swept into the cistern, and being diffused mechanically through the water as well as being partly dissolved, it produced those dangerous results already mentioned. The cure was somewhat expensive, and consisted in the removal of the lead-pipe and cistern, and the substitution of stoneware and slate.

It appears that neither hard nor soft water is safe in leaden cisterns if it contains organic matter in solution. This important fact has been established by Dr. Medlock, and he is of opinion that if the dissolved organic matter is allowed to remain in the water, it decomposes, attacks the lead, and forms a soluble nitrite of lead; and he has further ascertained that by exposing water which contains organic matter in solution to the action of iron, it has no longer the power to dissolve lead, and hence he has explained those otherwise apparent anomalies of some kinds of soft water not attacking lead, whilst other hard water containing the so-called protective salts dissolve lead freely. In the former case, the water was free from organic matter; in the latter, the hard water contained organic matter which produced the soluble nitrite of lead; therefore Dr. Medlock insists upon the freedom of water from soluble organic matter which is to be stored in leaden cisterns. Lead is not only used

to cover the houses which shelter the living, but has also been employed from time immemorial in the construction of the box or coffin to contain the dead. Formerly no person could be buried in a vault under a church except in a leaden coffin; the barbarous custom of putting the dead in leaden cases that were liable to swell, burst, and throw out their deadly gases into the church above containing the living, has now been abolished, except in rare cases, when embalmed royalty, or the remains of some of our greatest men are consigned to their last resting-places in Westminster Abbey, St. Paul's, or the Chapel Royal, Windsor.

Mr. R. V. Tuson has made an interesting analysis of coffin-lead taken from an old coffin which had lain in a vault, it is believed, for eighty years, and obtained the following results. The pieces of lead were about a quarter of an inch in thickness; they had a laminated structure, and possessed a fawnish or dead-white colour. Neither crystalline form nor metallic lead were detected, even by the aid of the microscope. The material was tolerably brittle and readily reduced to an impalpable powder. On submitting it to quantitative analysis, the following were the results obtained:—

Moisture	0·10
Organic matter and loss	0·52
Peroxide of iron	1·94
Oxide of lead	82·29
Carbonic acid	15·15
	100·00

These results show that it chiefly consisted of proto-carbonate of lead, with a small proportion of anhydrous protoxide. The interesting points in connexion with this substance are, that it is anhydrous, that it contains but a small excess of oxide, and that it consequently differs in composition from any of the carbonates of lead hitherto described as being produced by the united action of air and water on metallic lead, or by the influences concerned in the well-known Dutch method for manufacturing "white-lead." The difference in composition of the various carbonates of lead formed under the circumstances referred to, will be seen by glancing at the subjoined table:—

Source.	Composition.
Air and water in lead. . .	$PbO, HO + PbO,CO_2$
Dutch method	$PbO, HO + 2(PbO,CO_2)$
Leaden coffins	$PbO, + 15(PbO,CO_2)$

The searching and exposure of the condition of the vaults of many of our crowded churches by Mr. George Godwin, Mr. Walker, and other gentlemen, has induced the sanitary authorities to order them to be closed and filled with charcoal, and that this was absolutely necessary, is apparent from the vignette at the end of this chapter (Fig. 159), which shows the condition and number of coffins containing decomposing animal matter stowed away under the ancient crypt of Bow Church, and called *a Christian* burial.

Experiments with Lead.

First Series.

To make an assay of lead ore or galena, a fair average sample must be selected, and after being powdered, 150 grains may be weighed out and mixed with 230 grains of black flux and 50 grains of moderate-sized nails, and the whole placed in a proper crucible, which is then to be brought to a bright red heat. When the whole is in a perfectly liquid state, the crucible may be removed, gently tapped, and allowed to cool. On breaking the crucible with a hammer, a button of lead will be found in the lowest part, which may be flattened out on the anvil, to remove any of the adhering flux or parts of the iron nails. The weight of the button of lead determines the per-centage of the metal in the ore, and to ensure accuracy, the assay should be repeated three times, and the mean of the experiments taken. The furnace and crucible for this operation are shown at Fig. 156, and Messrs. Griffin, of Bunhill-row, Finsbury, make most convenient portable furnaces for all kinds of assays. The button of lead may be subsequently cupelled, and the number of ounces of silver it contains per ton accurately determined.

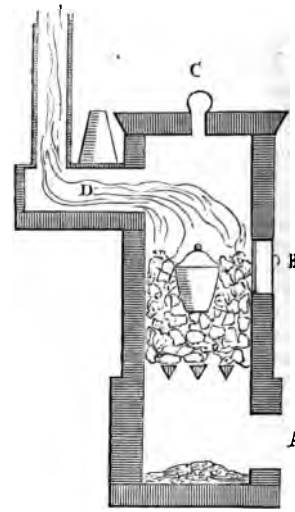


Fig. 156. Common sheet-iron Furnace lined with fire-clay, for ordinary metallurgical operations not requiring an intense heat. A. Ashpit and sliding damper. B. Side hole, with door for fuel. C. Cover lined with fire-clay and hole in centre. D. Chimney.

Second Series.

A very instructive experiment, illustrating the reduction of a metal from the state of oxide, is performed by mixing one ounce of litharge or red lead with three of powdered cyanide of potassium, and placing the whole in a crucible, which is then brought to a dull red heat in an open charcoal brazier or common fire. The carbon of the cyanogen removes the oxygen from the oxide of lead, and directly the whole is properly fused, the slag may be carefully poured off into an iron shovel, and the heavier lead into a greased mould (the top of a 1-lb. brass weight is as good as anything), and then after being cooled in water, may be hammered on the anvil to show the malleability of the

metal when the oxygen is separated from it. The powdered litharge is a dust or powder that the wind from the bellows may blow away, but deprived of the combined oxygen, a solid and heavy mass is obtained, upon which the air from the bellows has no effect. The powdered litharge preserves a dull ash-grey colour, but like the fabled phœnix bird of old, it is revived by the action of fire and charcoal, and is changed to brilliant and shining lead.

Third Series.

The reduction of lead to the metallic state and its subsequent oxidation, can be displayed in another and more curious form by heating some tartrate of lead in a glass tube about eight inches long and three-eighths of an inch wide, closed at one end, and drawn out to an open capillary tube at the other. The perfectly dry tartrate of lead should be placed in separate lengths of the narrow glass tube, previously closed at one end, and after its admission, the tube may be drawn out into an open capillary tube at the other extremity, so that when heated over a wire-gauze burner of gas and air, the capillary end may be hermetically sealed, directly after the smoke has ceased to be evolved from the heated tartrate of lead. When the tube is cold, and one end broken off with a pair of nippers, the finely-divided lead takes fire as it is shaken out into the air, forming litharge, which is very apparent when the tube containing the pyrophoric lead is emptied into a tall jar containing oxygen gas. That the effect is due to the oxidation of the metal is clearly demonstrated by shaking some of the contents of the tube into another tall jar containing carbonic acid gas, when the spontaneous combustion of the lead no longer occurs, and the yellow colour of the litharge is

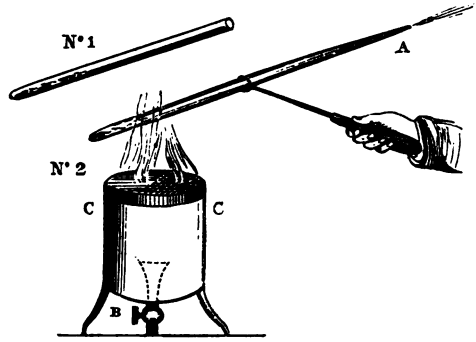


Fig. 157. No. 1. Tube closed at one end, containing tartrate of lead. No. 2. Ditto, closed and drawn out to a capillary tube at A, and held over the mixed gas and air flame obtained by allowing coal gas to escape gently from the cock B into the iron cylinder C C, open at the bottom, and covered with wire gauze at the top, where the mixture of gas and air burns.

not apparent on the sides of the jar containing the latter gas, whilst it is very easily seen in the jar containing the oxygen.

The tartrate of lead is readily procured by precipitating a solution of acetate of lead with one of tartaric acid previously neutralized, or nearly so, with ammonia. The precipitate may be separated and washed with water by decantation, or it may be collected on a cotton cloth filter, washed with water, squeezed by hand or with a press, and finally dried in an oven.

Fourth Series.

Pure lead is frequently required in the assay of gold or silver, and is obtained by calcining pure nitrate of lead in a crucible, and then fusing the residual oxide with charcoal, or, still better, with cyanide of potassium, when a button of the pure metal is obtained.

Fifth Series.

Lead is deposited from a solution of acetate of lead in a very beautiful crystalline metallic state, by placing in the solution a bar or rod of zinc. The first effect of the latter is to take away a portion of the acid and oxygen from the acetate of lead, and when a portion of the lead is deposited on the zinc, the electro-chemical deposit proceeds slowly by the action of the voltaic couple, and whilst the oxygen and acid pass to the zinc which is dissolved, the lead assumes the solid state, and clings to the remains of the rod of zinc, producing a pretty ornament, called the lead or Saturn's Tree. An engraver's glass globe is well adapted to show off this very brilliant and pretty deposit of lead.

Sixth Series.

On the small scale, the reduction of litharge or red lead to the metallic state may be shown by mixing the latter with powdered coke or charcoal, and placing it in the bowl of a tobacco-pipe, using the stem as the handle. On the application of a dull red heat, the charcoal combines with the oxygen of the litharge, and escapes as carbonic acid, and the lead gradually collects at the bottom of the bowl, and may be poured off into a mould or on damp sand. Lollypops suspected to contain lead as the colouring pigment, may be treated in a similar manner, and although it takes a longer time to burn off the excess of carbon, the lead finally becomes apparent, either in minute globules diffused through the mass of charcoal, or collected in a larger quantity at the bottom of the bowl.

Seventh Series.

Lead unites with oxygen in various proportions, but the chief oxides are the

Suboxide of lead	Pb_2O
Oxide of lead	PbO
Binoxide of lead	PbO_2

The suboxide (Pb_2O) is obtained by heating oxalate of lead in a green glass test tube, placed in an iron ladle containing melted lead (a lead bath), until the whole of the carbonic acid and carbonic oxide gases are given off. The lead bath should be maintained at a temperature just sufficient to keep it from solidifying. Oxide of lead (PbO) in the fused state, under the name of *litharge*, is prepared in the manner already described, during the cupellation of lead for silver on the large scale. Oxide of lead which has not been fused or heated, or only moderately so, presents a lemon or orange yellow colour, and is called *massicot*. At a high red heat the latter fuses, and if of a red colour from the presence of minium or red lead, is called *litharge of gold*; but if paler, is termed litharge of silver. The presence of sulphuret of antimony in minute proportions imparts a dark hue to the litharge.

The binoxide of lead (PbO_2) may be prepared by digesting minium with strong nitric acid. The acid and oxide must be constantly stirred, and after a few days a dark brown powder is formed, from which the acid solution of lead must be poured, and the whole well washed with an abundance of boiling water, and the residual binoxide carefully dried in a water bath. The operation is quickened by boiling the nitric acid.

Common *minium* or red lead is prepared by exposing oxide of lead to the action of a current of air heated to a temperature between 570° Fah. and 580°. The finest and most brilliant *minium* is prepared by exposing carbonate of lead to the action of a current of air heated to about 600° Fah.

Eighth Series.

Chlorine, iodine, bromine, and fluorine unite with lead. The chloride (PbCl) is prepared by precipitating a strong solution of acetate of lead with hydrochloric acid or a solution of common salt; on boiling the solution the precipitate disappears, as 1 part of chloride of lead dissolves in 135 parts of cold and 33 of boiling water; therefore, when cold, the chloride of lead again deposits in beautiful crystals, and is called the "*silver shower.*"

"*The golden shower,*" so called, is prepared by precipitating a solution of acetate of lead with one of iodide of potassium; on boiling the mixed solution the iodide is redissolved, but again precipitates in pretty shining yellow scales, as the flask containing the solution is permitted to cool. The yellow precipitate is the iodide of lead (PbI).

The bromide of lead (PbBr) is prepared by adding a soluble bromide to a solution of lead, and resembles the chloride in its colour and properties. Amongst the various pigments obtained from lead there is a yellow colour called Paris, Mineral, Turner, or Cassel yellow, which is an oxychloride of lead of a variable composition, according to the manner of its preparation. When a solution of chloride of lead is decomposed with lime water the oxychloride is obtained, and being dried and calcined affords the yellow colour. If prepared by boiling with water four ounces of litharge and one of common salt, the oxychloride

obtained is white, but assumes a yellow colour after calcination, and its composition is represented by the next formula, PbCl,3PbO,HO.

Fluoride of lead (PbF) is obtained by adding hydrofluoric acid to a solution of nitrate of lead, when it precipitates as a white powder, which is almost insoluble in water.

Ninth Series.

Ceruse, white lead, or carbonate of lead (PbO,CO_2), is prepared in enormous quantities for white paint. By precipitating a solution of lead with carbonic acid or any alkaline carbonate, a carbonate of lead is obtained which appears to have a semi-crystalline form, and is not sufficiently dense and opaque, or has not sufficient body to cover the work when used as paint, consequently the ceruse prepared by the old Dutch methods is generally preferred. This process was introduced into England in 1780, and is conducted with lead which is cast into plates, bars, or grates, and arranged in conical earthen pots containing about a gill of acetic acid, and placed in stacks surrounded with dung, or, better still, with spent bark. The stack, contained within an oblong brick chamber, is built up of alternate layers of dung or tan, the pots containing the lead and acetic acid, boards, more dung or tan, and so on till the stack contains about twelve thousand pots, and from fifty to sixty tons of lead. The tan or dung gradually ferments, and attains a temperature of about 140° or 150° Fah. in the central part of the stack, and in the course of four or six weeks the lead increases in bulk, and although retaining its form, is now converted into a dense basic carbonate of lead, having the formula of 2, sometimes 3 (PbO,CO_2) PbO,HO. The affinity of lead, or rather, oxide of lead, for carbonic acid, is very remarkable, and may be observed sometimes on the exterior of leaden water pipes which pass near drains evolving carbonic acid and other gases. Even near the ventilating door of a roof of any public building covered with lead, when the foul air escapes and impinges on the metal, the same change is observed, and when it once begins, the attacking carbonic acid cuts like a cancer into the very body of the lead. Sometimes white lead is adulterated with sulphate of baryta, called *Venice white*, but a very simple analysis will detect the sophistication.

Tenth Series.

Other valuable pigments are obtained by the combination of chromic acid with oxide of lead, which may be either yellow in the state of neutral chromate of lead (PbO,CrO_3), or a beautiful red, as bibasic chromate of lead, 2 PbO,CrO_3. The former is prepared by precipitating a dilute solution of acetate of lead with one of chromate of potash, and the addition of sulphate of lime to the commercial chromate is said to improve the colour. The red dichromate is formed by digesting the yellow chromate of lead in caustic potash, or still better by Liebig and Wohler's process, in which the neutral chromate is added to melted nitre, and when the red chrome has subsided the melted nitre above it is poured off and the remaining mass quickly washed with water.

Eleventh Series.

All pigments containing lead must be preserved from contact with sulphuretted hydrogen gas; white lead especially is peculiarly sensitive to the presence of that gas, and hence the use of tan is preferred to that of dung in making white lead, because of the sulphuretted hydrogen sometimes emitted from manure in a state of fermentation. In the neighbourhood of large gas works the paint of the houses is sometimes strangely affected from the same cause, and the author has seen a whole row of houses rejoicing in fresh paint and cleanly cheerfulness, changed in the course of a few days to a most dismal and funereal aspect by the sulphuretted hydrogen escaping from gas purifiers, which have been carelessly emptied and their contents allowed to remain exposed to the air.

Sulphide of lead (PbS) occurs plentifully in nature as an important mineral, which has been already spoken of by the name of *galena*. It is prepared artificially by melting sulphur with lead, or by precipitating a solution of acetate of lead with sulphuretted hydrogen gas, when the sulphide presents a black colour, or a deep brown if a solution of sulphide of ammonium is employed; and a very marked result is obtained by writing on a sheet of paper the words sulphide of lead with a solution of acetate of lead mixed with some glycerine to keep it damp; and if a little sulphide of ammonium is poured into a wide-mouthed stoppered bottle and shaken, so as to diffuse the vapour through it, on removing the stopper and applying the bottle to the letters, they become visible immediately, and change to a deep brown colour, the lead being precipitated as the sulphide.

Fig. 158. Invisible Letters written with a solution of lead becoming visible by holding to them a bottle containing a few drops of sulphide of ammonium well shaken in it to diffuse the vapour through the air contained therein.

The presence of sulphur in albumen is easily shown by dissolving some white of egg in a solution of caustic potash, and adding one of acetate of lead, as long as the precipitate formed is redissolved. On boiling the solution it instantly becomes black by the separation of sulphuret of lead, which proves in a satisfactory manner the presence of free sulphur.

As hair is allied to albumen in composition, and likewise contains free sulphur, leaden combs are frequently used to darken it, and a hair-dye composed of litharge and cream of lime has been recommended for changing red hair to a blackish hue.

Twelfth Series.

The tests for lead are well marked in the results they produce.

A solution of sulphuretted hydrogen precipitates lead from its solution as a black sulphide, when free from excess of acid; if the latter preponderates, it must be neutralized by ammonia or carbonate of soda before using the test.

A solution of sulphide of ammonium affords a deep brown-coloured precipitate in solutions of lead free from an excess of acid.

Potash precipitates the hydrated white oxide of lead soluble in an excess of potash, and more decidedly when the latter solution is hot than cold.

Hydrochloric acid or a solution of salt precipitates the chloride of lead soluble in boiling water, and very insoluble in cold.

Iodide of potassium precipitates the iodide of lead, which, if dissolved in boiling water, and allowed to cool, separates again in beautiful golden spangles. The solution of lead must be neutral.

Sulphuric acid throws down a white precipitate of sulphate of lead, which may be collected, washed, dried, and reduced by black flux to the metallic state. Sulphate of lead is nearly insoluble in water, and very slightly so in dilute sulphuric or nitric acid; it is soluble in the alkalies and in tartrate of ammonia, so that the presence of certain salts of ammonia may interfere with its precipitation.

Chromate of potash precipitates the beautiful yellow chromate of lead soluble in nitric acid.

The formation of the crystalline deposit of lead called the *lead tree* in a solution of lead by a piece of zinc is very characteristic of the metal.

Thirteenth Series.

Type-metal is composed of one part antimony and four parts lead, with a little bismuth.

Common pewter is made by melting together eighty parts of tin and twenty of lead.

Plumber's solder is made of equal parts of lead and tin. Three equivalents of tin and one of lead make the most fusible alloy.

Tea-lead, or the metal used by the Chinese for the lining of the tea-chests, consists of nine parts of lead with one of tin.

Shot-lead appears to owe its property of taking the spherical form when melted and poured through a colander placed on an upper floor of a lofty tower to the presence of a certain quantity of arsenic, amounting to $\frac{3}{10}$ths to $\frac{8}{10}$ths per cent. The addition of too much arsenic causes the shots to be like a double convex figure, or to be pear-shaped when too small a dose of arsenic is added to the melted lead. The sieve or

colander is prepared inside with the dross scraped off the surface of the melted lead, seemingly to prevent the melted lead adhering to, or, as it is termed, *wetting* the surface of the colander, so that the lead may flow or drop directly through the orifices. An ingenious person at Newcastle constructed a shot manufactory out of a deserted coal-shaft, and thus escaped the cost of building a tower like that we see near Waterloo Bridge.

Fig. 159. Ancient Crypt under Bow Church, showing the Arrangement of the Leaden Coffins.

Fig. 160. The new Bronze Penny Piece.

CHAPTER VII.

COPPER. ♀

The symbol is supposed to represent the looking-glass of Venus.

An old author, describing this metal, says, "Æs, or copper (which was so called from the Isle of Cyprus, where it was first gotten in great plenty), is a metallick body, participating of a fuscous or darkish redness, being ignible and fusible, and is as the mean betwixt gold and silver, and is generated of *argent vive* (quicksilver), impure, not fixt, earthy, burning red, not clear, and of such a sulphur, it wants fixation, purity, and weight." The author's name is Webster, who wrote a "History of Metals," and, not content with his own description, he also quotes that of Cæsalpinus, "That copper doth in colour imitate gold, for if its redness be a little diluted, it becomes *aurichalcum* (brass), most like to gold; and that it imitates silver in its tractable substance and slowness of fusion, for it requireth ignition before it be melted. But it differs from both, because it doth not bear the trial of fires (as they do), but is universally burnt; from whence it is noted to contain much of combustible exhalation, far above the rest of the metals it yieldeth a sulphurous smell and flame. Besides being modified, it doth most easily contract a rust, which is called ærugo, of a green colour."

Although garnished with many pedantic words, the above description affords a tolerable account of the most prominent qualities belonging to copper, which was called "Venus" by the alchemist; not, it appears, on account of any remarkable metallic charm, as Webster states "that it participates of a *fuscous* or darkish red," but in consequence of its easy union with other metals, and the change which ensues in its nature and appearance.

Werner conjectured that copper was the first metal worked by man, and Jamieson observes that "this opinion may be considered as very probable, especially when supported by the account which is given of some of the native tribes of the north-western parts of America, who, though little civilized, have applied to domestic purposes the native copper with which their country abounds. It is also known that at a very early period, domestic utensils and instruments of war were made of a compound of this metal and tin; even during the Trojan war, as we learn from Homer, the combatants had no other armour but what was made of bronze, which is a mixture of copper, tin, and zinc. Macrobius, who wrote in the fourth century, informs us that when the Etruscans intended building a new city, they marked out its limits with a coulter of brass, and that priests of the Sabines were in the habit of cutting their hair with a knife of the same metal.* The Greek and Roman sculptors executed fine works of art in porphyry, granite, and other hard minerals by means of their copper instruments. The great hardness of the ancient copper instruments induced historians to believe that the ancients possessed a particular secret for tempering copper, and converting it into steel. There is no doubt the axes and other ancient tools were almost as sharp as steel instruments, but it was by a mixture with tin, and not by any tempering, that they acquired their extreme hardness. Axes and other instruments of copper have been discovered in the tombs of the ancient Peruvians, and also in those of the early inhabitants of Mexico. These were so hard, that the sculptors of these countries executed large works in the hardest greenstone and basaltic porphyry; their jewellers cut and pierced the emerald and other precious stones by using at the same time a metal tool and a siliceous powder. Humboldt brought with him from Lima an ancient Peruvian chisel, in which M. Vauquelin found ninety-four parts of copper and six of tin. This mixture was so well forged, that by the closeness of the particles its specific gravity was 8·815, while, according to the experiments of M. Briche, chemists never obtain this maximum of density but by a mixture of sixteen parts of tin with 100 parts of copper. It appears that the Greeks and Romans made use of both tin and iron at the same time in the hardening of copper. A Gaulish axe found in France by M. Dupont de Nemours, which cuts wood like a steel axe, without breaking or yielding, contained, according to the analysis of Vauquelin, eighty-seven of copper, three of iron, and nine of tin."†

Europe, Asia, North and South America, and Australia are all well supplied with deposits of copper ore, and England specially has been remarkable for centuries as containing in Cornwall numerous copper mines. It occurs in this locality in veins that traverse granite and clay-slate, along with tinstone, red copper ore, common quartz, rock-crystal, &c.

The ores of copper are somewhat numerous, and although they are

* Macrobius, Saturnalia, lib. v. cap. 19, p. 29. 512.
† Humboldt's New Spain.

not to be distinguished by any one particular external appearance, they are easily recognised by the action of a solution of ammonia upon them. A little of the mineral suspected to contain copper may be powdered, heated on a bit of platinum foil, and then digested with ammonia. The production of a very marked blue solution serves to indicate the presence of the metal, which may be confirmed by the use of other tests described in the experiments with copper. Besides the blue water or solution of sulphate of copper which flows from certain copper mines, Jamieson enumerates twenty-three species, with other subspecies of copper ores—viz.:—

1. Native copper	In crystals, filaments, and branches.
2. Copper glance	Copper, sulphur, iron, and silver.
3. Variegated copper ore	Copper, sulphur, iron, and oxygen.
4. *Copper Pyrites*	Containing from 30 to 50 per cent. of iron, 12 to 36½ per cent. sulphur, and about 30 per cent. copper.
5. White copper ore	Copper, sulphur, iron, and arsenic.
6. *Grey copper ore*	Copper, sulphur, iron, arsenic, antimony, lead, and silver.
7. Black copper ore	Same constituents as No. 6, with the accidental addition sometimes of zinc and mercury.
8. Black oxide of copper	Oxygen, copper, and a little iron.
9. Red copper ore	Oxygen, copper, and a little iron.
10. Tile ore	
11. *Azure copper*	Oxygen, copper, carbonic acid, and water.
12. Velvet copper ore	Intermediate between Nos. 11 and 13.
13. Malachite	Copper, oxygen, carbonic acid, and water.
14. Anhydrous carbonate of copper	Oxygen, copper, a little iron, carbonic acid, and silica.
15. Copper green	Copper, oxygen, carbonic acid, water, silica, and sulphate of lime.
16. Ironshot copper green	Copper, oxygen, water, and silica.
17. Emerald copper ore	Copper, oxygen, carbonate of lime, silica, or copper, oxygen, silica, and water.
18. Muriate of copper, or atacamite	Copper, oxygen, chlorine, and water.

19. Phosphate of copper . . .	Copper, oxygen, and phosphoric acid.
20. Copper mica	Copper, oxygen, arsenic acid, and water.
21. Lenticular copper ore . . .	
22. Olive copper ore	
23. Cupreous arseniate of iron .	Copper, oxygen, iron, arsenic acid, water, and silica.

All these ores, which contain copper, are available for the purpose of extracting the metal, but copper pyrites and grey copper ore in England, and azure copper in France, are those usually found in the greatest abundance, and melted or reduced to the metallic state.

The copper veins or lodes of Cornwall present the most interesting geological arrangement of the mineral, and they chiefly occur in the *killas*, or greenish clay-slate, and sometimes in the "*elvans*," or granite, so that the Cornish miners work chiefly in these rocks, and especially near the line of junction between them. It has been already stated that the localities where coal occurs are usually termed "coal fields;" these are worked by different proprietors, and are confined to proper boundaries, beyond which no coal-owner may trespass. With minerals, when the lode traverses the land of several proprietors of ground, it is usual to call the respective divisions *setts*, which are worked at a fixed rental or a per-centage on the value of the ore raised, termed the *lord's dues*, amounting to about 6½ to 7 per cent. *A course* is a term used to signify a barren vein; but the word *lode* means a vein rich in mineral. The slope of the vein to the horizon is called the *underlie*, or *hade slope*, and when the vein divides into many smaller ones, like a cat-o'-nine-tails, they are called *strings;* and if the vein becomes still thinner, it is characteristically termed a "*thread*."

There are many systems of copper veins in Cornwall—viz., the rake vein, the pipe vein, the flat vein, and the interlaced vein, and all the skill, patience, and experience of the miners are sometimes demanded to recover the lode, which is thrust out of its natural position by intersections of worthless courses. In the article on lead the derangement of the course of a vein has been already depicted (Fig. 150); and to show how closely the old miners observed the positions of the veins of ore, the following cuts, taken from Agricola's ancient work, are introduced. They serve as ground plans, and give the reader a very fair notion of the complicated position assumed by veins in the earth, into which the spectator is supposed to be looking in a perpendicular direction. When the lode is thrust downwards, it is not called a "downthrow," as in coal mining, but a "slide;" and if forced upwards, it is said to be "heaved," which corresponds with the "upthrow" of the collier. The cavity containing the lode is necessarily surrounded by other rocks, which are called the *walls*, the top being the *hanging wall*, or sod, while the bottom of the bed is the *foot wall*, or floor. These terms are well

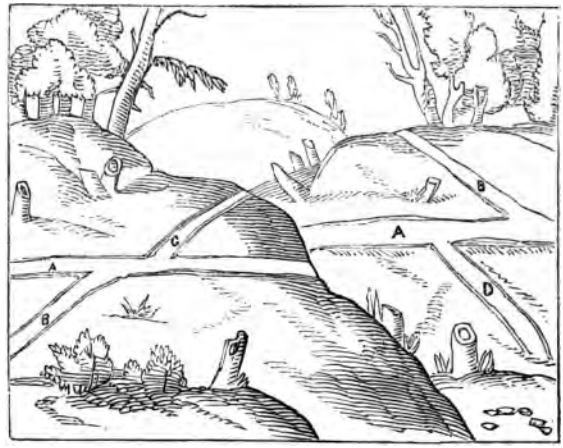


Fig. 161. A. chief vein. B. Intersecting or cross vein. C. The other part of B, removed from is natural position (rapta). The further removal and alteration of the original position and continuity of the vein is shown to the right at D A B. (Agricola.)

illustrated by the next diagram from Ure's "Dictionary," which is a section of the famous Boroondara and Bulleen gold mines near Victoria,

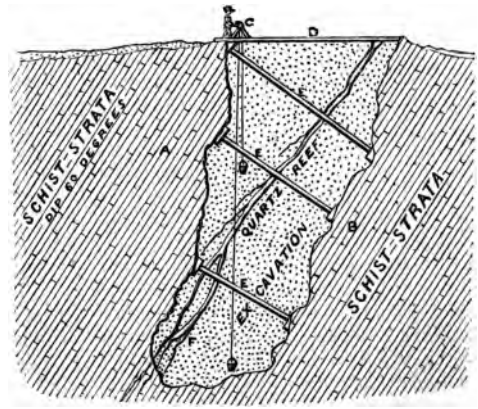


Fig. 162. Illustration of the Hanging Wall or Sod, and the Floor or Foot Wall.

in Australia. Here a vein of quartz containing gold fills a cavity in the schist strata, which dips at an angle of 60 degrees. The schist is, therefore, the walls of the vein, and if excavated properly, the *hanging*

wall or sod A, should be supported by the timbers, E, E, E, upon the *foot* wall B, whereas the quartz has been removed in the rudest manner, without taking these precautions; it is, therefore, a most dangerous working, and the *hanging* schistose wall at 60 degrees may fall at any time and annihilate the miners.

In the next cut it will be noticed that Agricola was desirous of giving a still better notion of the actual appearance and position of the mineral veins in the earth, and we have, in his rude attempt at a perspective view of the vein standing in a supposed section of the earth, an approach towards those correct and elaborate models of Mr. Sopwith, which delineate so clearly the actual mechanism of faults, dislocations, cross courses, veins, and lodes.

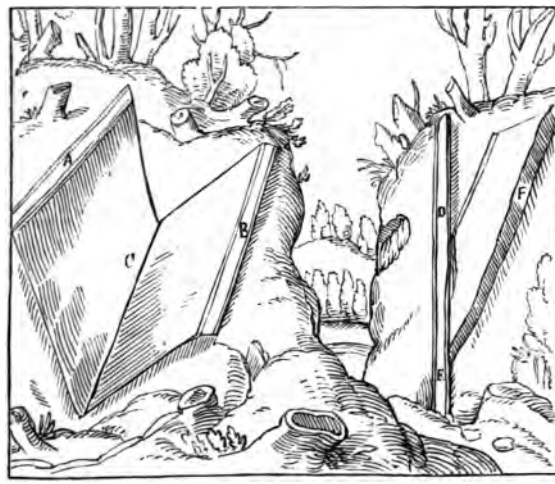


Fig. 163. A B. Two veins, both of which descend obliquely, so that one passes into or intersects the other. C. The point where they meet. Two veins, again, of which one, marked D, descends straight into the earth, and the other, marked F, obliquely, which passes into or intersects the other at E. (Agricola.)

The veins of copper ore vary in thickness from a few inches to several yards or fathoms; they may dip down to profound depths beyond the limits of mining, and have been known to extend for miles within the industrial grasp of the intelligent miner. A loose earthy substance, containing oxide of iron, and of a somewhat crumbly nature, as if it was in a state of decomposition, called *gossan*, or "gozzan," is regarded by the Cornish miners as the *avant-courier* of a vein of copper ore. Gossan usually lies on the back of the vein, and as it frequently outcrops or comes to the surface of the earth, the plough has often been the first

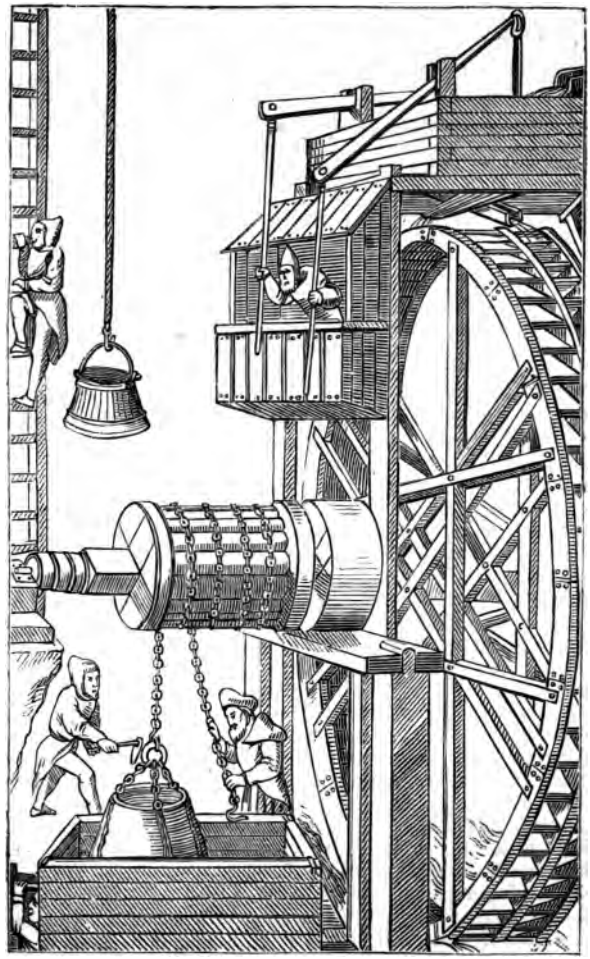


Fig. 164. Mouth of a Copper Mine, with simple mode of reversing motion of the chain on the shaft by two overshot water-wheels. (Agricola.)

instrument which has disturbed it, and awakened the attention of the shrewd miners to the presence of copper.

The author, whilst paying a visit to Tavistock, took the opportunity of visiting one of the richest copper mines in the county of Devonshire, called the "Devon Great Consols," formerly known by the name of "Huel Maria;" "huel" being an old Cornish word signifying a hole. Here the visitor has an opportunity of witnessing the operations of copper mining involving the use of water-power on the grandest scale. The immense size and power of the water-wheels, one of which drains the mine, and the other forces water over the hill to supply the dressing-floor of the mine, strike the visitor almost with awe, as he watches their steady and magnificent rotations. Walking up to the main shaft of the mine, the traveller has no difficulty in finding the way, as he has only to follow the enormous iron rod which connects the water-wheel with the pumping gear. This iron rod, or rather a succession of jointed rods, is 1740 feet long, or about the third of a mile, and it lifts at every stroke a large quantity of water to the adit level. The weight of this pumping apparatus amounts to 500 tons. These water-wheels are placed in a most romantic and beautiful country, and are situated on the banks of the river Tamar, near Tavistock. A steamer will take the tourist from Devonport to Calstock, and the route thence to the "Huel Maria" copper mine passes through a most interesting country, where the water-wheels may be numbered almost by hundreds.

The tools used by miners have already been alluded to, but when the rock is too hard to be penetrated by ordinary manual labour, gunpowder is employed. Formerly a hole was drilled in the rock, then dried out with tow, the charge of gunpowder being inserted, clay was stamped in, and it was finally connected with the surface by a rush (from which the pith had been removed) filled with gunpowder, the rush, or train, being inserted into the hole left after the *nail* (a small taper rod of copper, tamped and crammed round with clay, or any soft species of rock) had been removed. A paper quick-match, or "swift," adjusted to burn a certain time, is fixed on the top of the rush filled with gunpowder, so as to give the men sufficient time to get out of danger; but, as may be easily conceived, accidents frequently arose from the careless adjustment of the "swift," which either burnt too quickly, or, hanging fire, from dampness, the miners would approach to ascertain the cause of the apparent failure, when the mine probably exploded, and projecting the pieces of rock outwards with the force of a cannon, killed and wounded many men. The danger of blasting is now greatly reduced by the use of the improved *tamping* bar faced with bronze or hard copper, and the employment of "Bickford's fuse," which consists of a pyrotechnic mixture enclosed within a tube of hemp well protected from damp by a resinous coating. This fuse is so impervious to moisture, that it can be connected with a bladder containing gunpowder, and, being set on fire, the bladder may be drawn under the water. The composition inside the Bickford's fuse continues to burn until the fire reaches the powder, when the usual

explosion takes place. The ignition of iron or platinum wire by the voltaic current has also been most successfully applied as a means of firing the gunpowder; and the latter method has one great advantage, because it enables the miner to ignite a number of mines at one and the same moment instead of firing them in succession, and probably weakening the effect of the second or third shot by the explosion of the first having shaken or cracked the surrounding rock. It is also stated that the saving of time is very great, and that as much blasting may be performed by voltaic ignition in three months as would have required twelve by the old method with the rush train. The trouble, however, of attending to the voltaic battery, and the remarkable cheapness of Bickford's fuse, have caused the latter to be preferred by the practical man.

The introduction of gunpowder in the year 1615 completely revolutionized the art of mining, as it had done previously with the art of war; and soldiers bravely resisting the enemy, as at Inkermann, have been compared to solid walls and hard rocks which even gunpowder can move but slowly. The effect of gunpowder in blasting appears to be greatly increased by leaving a space of air above it; and this result was very apparent to the author in devising an experiment to show the mode of firing infernal machines beneath ships, as practised by the Russians before Cronstadt. When a certain number of grains of gunpowder were fired in a small close bladder-case under a model of a ship, no effect was produced, whilst the same number of grains of gunpowder enclosed with a large quantity of air, and fired, blew the model ship from the surface of the water with great force and power.

Fatigued by previous exertion, the author was not disposed to encounter the hard labour of ascending and descending the tedious ladders of the main shaft of the copper mine. Indeed, the descent of mines in Cornwall astonishes the stranger, who is surprised to notice the absence of those mechanical appliances of the rope and corve worked by the steam-engine, which render the descent and ascent of coal shafts in the neighbourhood of Newcastle and Durham so easy. The waste of the strength and time of the miner must be enormous. But there is another reason why the old climbing method should be abandoned, viz., its frightful effect on the health of the miner, who, after the fatigue of his work, conducted frequently in an atmosphere which produces the most distressing pulmonary complaints, is obliged to pull himself and mining tools upwards through a depth of twelve or even eighteen hundred feet; or, as has been calculated, the miner must perform an amount of work equal to lifting fifty tons one foot high in order to reach the surface of the earth. It has been estimated that many miners have thus to make an exertion *every night* equal to climbing to the summit of Cader Idris, and this in a shaft frequently used for the purpose of an air sewer to remove the foul air from the depths of the mine.

Stimulated by the offer of the high premium of 500*l.* from the Royal Cornwall Polytechnic Society, the Tresavean and United Mines were the first to adopt a "man machine," which consists of a long and con-

tinuous wooden beam, or iron rod, descending through the whole length of the shaft. This long rod is connected with a working beam, which

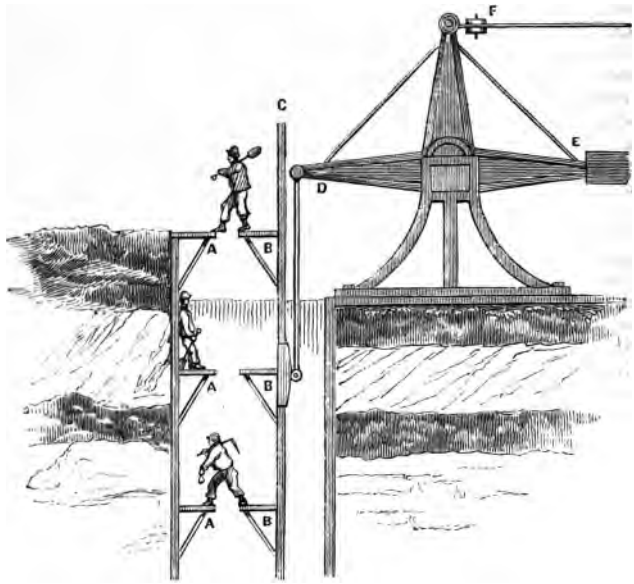


Fig. 165. "The Man Lifter," showing the fixed stages, or shelves, A, A, A, and the moving ones, B, B, B, attached to the rod, C, which is worked by the arm counterpoised by E. The pull is given at F. The man lifter is adopted at the Tresavean mine, which is 350 fathoms deep, and formerly occupied the miners one hour and a quarter to ascend by ladders placed nearly perpendicular.

communicates to it a stroke or movement of twelve feet. The beam is worked by steam- or water-power, and attached to the long rod, at the intervals of the length of the stroke—viz., twelve feet—are placed shelves sufficiently large to carry two men. The mere act of moving the rod, with the shelves attached, up and down, would of course be useless; but at the same intervals, and attached to the side of the shaft, are other *fixed* shelves; consequently, the miner has only to step from the latter to the moving ones to be lifted twelve feet each time, and to be gradually and safely transported to the surface. Where this invention is used, it is stated that the health of the miner is greatly benefited, and that heart disease, induced by the strain of climbing the almost endless ladder, is no longer prevalent amongst them. The mortality amongst the hardworking miners would be greatly decreased if the use of these man machines were insisted on, with proper enclosed

lavatories for washing, so that the miners, after sustaining the close heat of the deep mines, which usually stands at something like 80° Fah., should not be exposed to the cutting winds that assail him at the surface of the mine during the cold months of the year. Thus, in Redruth, which abounds in copper mines, it is stated that in every 100,000 of the population 220 males die of pulmonary disease more than females. This is not so bad as the lead-mining districts, where the excess is 320 in every 100,000, and the death rate of the men is double that of the women. In the tin mining districts of Penzance the superior waste of male over female life in the mining population of all ages is 104.

From the mouth of the shaft the visitor proceeds to that part of the works where the ore is "cleaned" or "dressed," and it may be observed that the miners below take care to select the proper ore to send to the surface, and use the rubbish to fill up holes or any vacant spaces in the mines; if obliged to send up the "deads," it is kept separate from the ore. The large stones containing the copper ore are broken by men and then arranged in three divisions—viz., "the deads or attle," "the pure ore," and "the best ore;" this latter is frequently broken again into smaller pieces, or "cobbed," by females, who, reclining on shelves or floors placed a few feet above the ground, and under a rude cover or roof, select the best portions of the ore and occasionally relieve their labours with low, soft, and melodious choruses which sur-

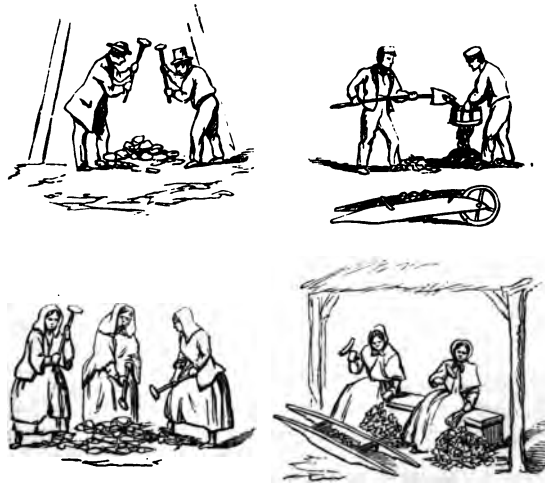


Fig. 166. Ragging, Spalling, Riddling, and Cobbing the Copper Ore.

prise the stranger, who looks with pitying eyes on these poor women doing such rough work and so exposed to all the changes of the weather. It is unnecessary to add, that "consumption" here is scarcely less fatal with these young women than with the underground workmen.

The sorting and division of the broken ore is of course conducted with great care and discretion, and it is now conveyed either to the stampers or crushing mill, already described in the chapter on lead, and then "riddled," or passed through a sieve having meshes of certain dimensions. The first-class copper ore is passed through a coarse riddle, the "poor ore" through one having finer meshes. To separate the earthy from the mineral particles, a process called "jigging,"

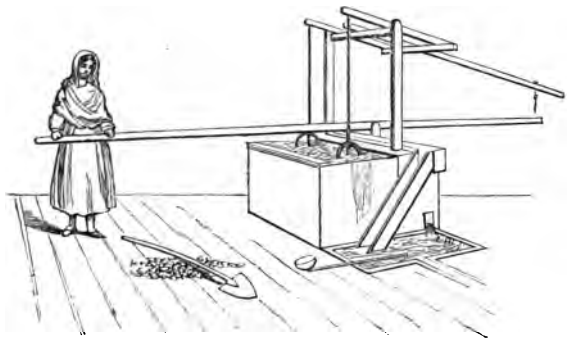


Fig. 167. The Jigging Machine.

is used, by which the powdered and riddled mineral is placed in a sieve formerly worked by hand, but now by steam-power. The sieve receives a constant motion in a cistern of water, and the principle of specific gravity determines the separation of the heavy from the light, earthy, and worthless particles. If a number of marbles and leaden bullets are placed in a sieve separately by hand, so that the two are thoroughly mixed, they may be again separated into two layers, the lead being at the bottom and the marbles at the top, by giving the sieve a constant succession of half turns or rotations with an upward jerk, and if this is done under water with smaller particles, like the "riddled" ore, the rich mineral sinks to the bottom of the sieve, whilst the earthy matter is found at the top, the intermediate position being filled by the ore, having more or less siliceous matter adhering to it. The fine particles which pass through the meshes of the sieve sink partly to the bottom of the cistern, and are partly carried off by the water to other contrivances, where the greatest ingenuity is displayed in arresting the passage of the fine grains of ore, so that little or none is wasted, and the earthy matter only washed away. By crushers,

"jiggers," cylinders armed with spikes or paddles, riddles, and buddles, the ore is collected and prepared for sale, and being arranged in heaps or "piles," bearing a ticket or label, having the weight of the heap inscribed thereon, samples are removed by intending purchasers for a preliminary "assay." The sale, or ticketing, is conducted in silence; each person proposing to buy deposits a piece of paper with his price and name in a glass goblet, and the auctioneer, called the clerk of the ticketings, afterwards removes and opens the papers, and finally adjudges the ore to the highest bidder.

Mr. Oxland, the learned consulting chemist of Plymouth, in the valuable work entitled, "The Useful Metals and their Alloys," makes the following remarks on the sale of copper ores, so far as it affects the prosperity of the Cornish miner, which, taken in conjunction with the statements made by a gentleman in the "Chemical News" of July 21st, 1860, appears to show that "monopoly" of any kind is opposed to progress and improvement, and tends to unequal dealing on one side, the poor or labour side, of course, being the loser. Mr. Oxland remarks, "That the system of submitting ores for sale by tender seems equitable, and calculated to give the miner the real value of his ores; but the competition is limited to too small a number completely to ensure this desideratum. The smelting of the ores is performed by about twelve firms; but the control of the trade, the regulation of prices and wages, and the prosperity of the miner generally, are in the hands of *three firms*, who collectively purchase more than a half of the total quantity of ores sold in Cornwall and Wales; while the purchases of six of the remaining nine firms do not amount to more than one of the larger ones. In consequence of this concentration of the trade in the hands of three private firms, the competition system, so far from affording the miner the value of his ores, is altogether *illusory*. . . . The baneful effects of a system which places such unlimited power in their hands, is only too apparent in the paucity of inventions emanating from the smelting interests."

In consequence of the comparative scarcity of coal in Cornwall and Devon, the copper ores are not smelted in these counties, but are taken to the coal fields of South Wales—viz., to Swansea and its immediate neighbourhood. Here the effect of the "copper smoke," as it is called, on plants, shrubs, and vegetable life in general, is very marked, and yet it is asserted that the effect on human life is not so great as might be expected. Leaving this question for the ultimate decision of those stern truth-tellers, the laborious and careful collectors of statistics, it is certain that large quantities of sulphur are annually wasted and carried off by the chimneys of the Swansea smelting works in the invisible form of sulphurous and sulphuric acids. The quantity of sulphur thus wasted is calculated to be equal to 50,000 tons weight per annum.

The per-centage of metallic copper in the ore when sold for smelting varies considerably, and a most elaborate "fire torture" is required to liberate the copper in a state of commercial purity. The furnaces em-

ployed are modifications of the "reverberatory furnace," and by the proper application of heat, air, and fluxes the metal is at last procured, after passing through at least eight operations, which are increased to ten when every stage of the economical adjustment of the process is taken into consideration.

No. 1. *Calcination*, or *roasting* by a reverberatory furnace to drive off matters volatile by heat—viz., sulphur, arsenic, zinc, and antimony.

No. 2. Melting by the stronger heat of a smaller reverberatory furnace the roasted ore with a small quantity of other unroasted ore containing a larger per-centage of copper, also some fluor spar and slag, when the "matt," or coarse metal, containing about thirty per cent. of copper, is run off into water or granulated, and the slag, or scoriæ, is raked off into moulds in sand, or regularly cast in iron moulds, and used for building purposes.

No. 3. *Calcination*, or *roasting* of the coarse or crude metal in a reverberatory furnace of the same kind as that used in the first operation for the purpose of driving off the volatile sulphur; the heat is urged to a point short of fusing the metal, and when completed, the granules of copper are found to be reduced in size, and are of a deep black colour, and they should consist of oxide of copper and oxide of iron.

No. 4. Melting by a reverberatory furnace the coarse metal with sulphuret of copper and certain slags, and again running the "matt" into water. The crude metal, called "white metal," now contains from seventy to seventy-five per cent. of copper, and chiefly consists of sulphuret of copper with about four or eight per cent. of sulphuret of iron.

No. 5. Melting for "blue metal." This operation is nearly identical in principle to that of the previous one.

No. 6. Remelting of slags, by a reverberatory furnace, from the fourth, seventh, and eighth process, for the purpose of procuring a "matt" in which the copper contained in these slags shall be brought together.

No. 7. *Roasting*, or *calcination* of the blue metal in a reverberatory furnace, and its conversion into white metal similar to that obtained from the fourth operation, and likewise for the expulsion of the different ingredients which are prejudicial to the quality of the copper.

No. 8. *Calcining*, or *roasting* in a reverberatory furnace, from regulus to procure a very white metal which contains about eighty per cent. of copper.

No. 9. Roasting and fusion of the regulus in a reverberatory furnace, and preparation of crude copper.

No. 10. Preparation of fine copper by the refining, polling, and toughening of the product of No. 9; also conducted in a modified reverberatory furnace.

It is stated that there are at least 500 furnaces at work night and day at Swansea, which consume nearly 500,000 tons of coal per annum; and, out of a population of about 30,000 souls, employ about 4000, who receive nearly 4000*l.* sterling in wages every week. It is not surprising that British copper should be the best in the world with such facilities and experience, but it is a remarkable fact that the economy of the process, so far as the saving of the sulphur is concerned, is not better attended to; but trade secrets leak out, and the following remarks by a scientific man, signing himself J. A., in the "Chemical News," explains the mysterious abnegation of that wealth which may be derived from the saving of the sulphur in the processes of copper smelting.

"A misunderstanding arose between the British Government and that of the kingdom of the Two Sicilies, some twenty years ago, respecting the shipment of sulphur from the island of Sicily, as the latter government had ceded to a French company a grant for the exclusive shipment of sulphur from that island. I was at that time engaged in the neighbourhood of Swansea, and noticed the amount of damage and nuisance caused by the escape of sulphurous vapours from the copper works; it struck me that this might be avoided, and that the sulphur might, at any rate, be made available for the forming of sulphuric acid.

"An opportunity was afforded me for trying some experiments on a pretty large scale, and I succeeded in obtaining sulphur from copper ore. The mode by which I obtained this was, however, not applicable to the existing plant and *modus operandi* of the established copper works. I was engaged for a length of time in devising some modification of my plan so as to adapt it to the existing order of things. I had opportunities of making propositions to one or other of the copper smelters from time to time, *which were always disregarded.* At length I thought of the plan of making a cheap preparation of iron to take up and retain all the sulphur in the slag. . . . . I devised an arrangement of furnaces for this purpose, so that the process of copper smelting might be conducted by one single continuous operation. I did not submit this plan formally to the copper trade as a body; but having special introduction to one of them on another subject, I incidentally introduced my ideas on copper smelting as above. This gentleman entered into my views very warmly, promised me all his individual assistance, and that every facility should be afforded me at their works for carrying my plan into operation. This occurred on my first interview. I had a particular engagement at that time which prevented me seeing this party again for two or three weeks; at the end of which time I sought a second interview, which I had great difficulty in obtaining. His manner was now completely changed; he would do nothing to assist me, and entered into a detail relating to the copper trade, some of which it would not be right to mention here; but what he did say amounted to this, that the copper trade was in a peculiar position, in the hands of half-a-dozen very wealthy firms, having a most perfect understanding amongst themselves; that if any plan came into use, this understanding would be broken up, a stop being put to the nuisance from copper works, and so

great a saving of fuel effected *that copper smelting might be carried on in almost any locality;* that the trade would thus become revolutionized.

"This conversation took place in 1848, the year in which revolutions were so much in fashion.

"Finding that the 'copper trade' was so decidedly hostile to any innovation, I abandoned this long-cherished project in despair, as I thought it in vain to submit it to any parties ignorant of the mysteries of copper smelting, since to any such, my scheme must have appeared altogether visionary."

It may be supposed that this letter will stimulate a few more capitalists to compete with the fortunate "half dozen," and that copper smelting "*will ultimately be carried on in almost any locality,*" to the great economy of sulphur, and the protection of the lungs of her Majesty's lieges.

It is right to mention that, although the complicated methods of smelting and refining copper are those which are generally pursued at Swansea, there are certain patented improvements that have been carried out to a certain extent, such as Blankart's, Rivet and Phillips's, Napier's, Davies's, Birkmyre's, De Sussex's, Low's, Parkes's, Trueman and Cameron's processes. It would, however, be foreign to the object of this popular work to describe them in detail, and therefore the reader is referred to Muspratt's splendid work on "Chemistry," or Phillips's "Metallurgy," or "The Useful Metals and their Alloys," for full informa-on the subject.

The water which flows from certain copper mines sometimes contains a considerable proportion of sulphate of copper, produced, no doubt, by the spontaneous decomposition and oxidation of the sulphide of copper. When the water contains a sufficient quantity to pay for the cost of precipitating the copper, it is collected in ponds, and all the old clippings of tin-plate, old battered iron pots and kettles, the refuse metal left after stamping out steel pens, iron borings,—in fact, iron in any shape as a waste product, is cast into the pond; when the usual change of places occurs, the iron is dissolved and the copper precipitated in a dark powdery mass. It was by attention to this simple fact that a poor Cornish miner realized a handsome fortune, and helped to lay the foundation of a great and now ennobled family. He was accidentally examining a part of the country to which he was a stranger, when his attention was directed to a little spring flowing from the hill-side that appeared to have a bluish appearance, being rejected by cattle and man, because it was said to be of a poisonous nature. Stooping down and dipping his knife into the water, he soon obtained that evidence of the presence of copper which is unmistakeable, and rightly conjecturing that the spring must flow from a mass of copper ore, he strongly urged the proprietor of the land to commence searching for this mineral. It is unnecessary to add that the search was entirely successful, and the vast heaps of "deads" or "attle" attest the enormous wealth obtained from this locality in the shape of copper ore.

This process of obtaining the copper from its natural solution in springs flowing from copper ores is called "cementation," and is conducted with profit at the "Paris Mountain Mine," in the island of Anglesea,

now connected with the mainland by the famous Menai and Britannia tubular bridges.

It is stated that copper mines have been worked in Anglesea from a very remote period, and that the Romans were acquainted with the Hamlet Mine, near Holyhead. The water is very limited in quantity at this mine; it contains a considerable quantity of copper in solution, and is precipitated by old iron in the manner already described. It is highly creditable to those who work and smelt the copper ores at Anglesea, that there they do save a portion of the sulphur.

In the Museum of "Practical Geology" there is a gilt copper cup obtained from the copper mine of Herrn-ground, in Hungary, and made from copper obtained by precipitation. The German inscription on the cup is, "God shows in me his great power, who out of iron makes copper;" and the date of this cup is about 1650.

One of the most curious instances of the precipitation of copper from its solution by metallic iron has been mentioned by Messrs. Varley and Lyell, in their report on the "Atlantic cable." This costly metallic rope appears to have been completely decomposed by the action of the sea-water, and was in such a rotten state, that even pieces of it could hardly be hauled on board without breaking. The report states: "The iron wires in many places often appeared sound, but on minute inspection, were found eaten away and rotten; the serving was also decayed. In some places the iron wires were coated with metallic copper and much eaten, they having most probably rested upon *copper ore*, for there are *veins* of it in *Trinity Bay*. The gutta-percha and copper wire are, however, in as good condition as when laid down. Those portions of the recovered cable that were wrapped with tarred yarn were sound, the tar and the hemp having preserved the iron wires bright and free from rust. This will be further reported on when the pieces of recovered cable have been more closely examined."

In the museum are also interesting specimens of sand from Perran Zabuloe, on the north coast of Cornwall, where the drainage-water, charged with sulphate of copper from a deserted adit, flows on to the sand of the beach, which contains a large quantity of carbonate of lime, in the shape of countless shells, and is there converted into a carbonate of copper, whilst the carbonate of lime is converted into sulphate of lime or artificial gypsum. This latter appears to act as a powerful cement, and Mr. Henwood states, that "so hard had this floor of copper, varying from one to eight inches thick, become cemented together, that it was found necessary to use gunpowder to remove it. . . . . The carbonate of copper is worth six pounds per ton, and this natural copper ore *manufactory* is still in operation, and must afford a good profit to the lord of the manor on which it is situated."

Mr. Henwood remarks, the hint ought not to be forgotten, as there are no doubt springs or streams of water flowing from copper mines which might be advantageously passed through great beds of roughly-broken limestone or chalk, mixed with some siliceous particles to assist filtration.

Sir R. Murchison considers that the formation of malachite (of which Russia furnished such magnificent specimens at the Great Exhibition of 1851) was probably caused by a somewhat similar natural process; and, speaking of an enormous mass of this mineral, calculated to contain half a million of pounds weight, and discovered at "Nijny Tagilsk," at a depth of 280 feet, he says:—

"The geological interest attached to this mass lies in the indication it affords that the substance called malachite has been formed by a *cupriferous solution*, which has successively deposited its residue in a stalagmitic form. *Mutatis mutandis*, this mass has only to be viewed as formed of calcareous spar (carbonate of lime), and it presents every one of the features so well known to those who have examined stalactite grottoes with their stalagmitic floors in the clefts and caverns of limestones, or still more those large masses of tufa (or soft calcareous stone formed by depositions from water) which have proceeded from calcareous wells. Whenever a portion of the malachite has been broken off, the interior is seen to consist of a number of fine laminæ (a fasciculus of radio-concentric globules), which invariably arrange themselves equally around the centre on which they have been formed, and are adapted to every sinuosity of the pre-existing layer, here presenting a dark line, there a bright and light one, just as the solution of the moment, the day, or the hour happened to be more or less impregnated with colouring matter. . . . . On the whole, we are disposed to view it as having resulted from copper solutions emanating from all the porous, loose, surrounding mass, and which, trickling through it to the lowest cavity upon the subjacent rock, have in a series of ages produced this wonderful subterranean incrustation."

A century ago several tin mines were abandoned when the miners came to the *yellows*, or yellow copper ore, because they said the *yellows cut out the tin;* but now the times are altered, and copper ore in any shape is gladly welcomed by the miner. At the Polytechnic, Mr. Tennant exhibited a great mass of native metallic copper from Lake Superior, in America, which is so tough that it cannot be blasted, and is usually cut out with sharp chisels; the mass exhibited was worth at least 300*l.*

The metal copper, when obtained in the pure state, has a remarkable red colour, and, as may be easily imagined, its specific gravity varies with its mechanical state, being from 8·6 to 8·95, which latter is the specific gravity of sheet copper or flattened copper wire. It melts at a temperature somewhere between that required for the fusion of gold and silver, and placed by Daniel at 1994° Fah. Like melted silver, it absorbs oxygen, when exposed in the liquid state to a current of air, which it again resigns with *spirting*, as it cools. Copper is very ductile, and the next in tenacity to iron; it conducts heat about two and a half times quicker than the latter. Copper takes an excellent polish, to the great delight of those who possess the metal in the shape of copper culinary implements, and this property has been depicted over and over again in the admirable works of Teniers and other great Dutch painters. *Copper precipitated* by a voltaic current always preserves a crystalline

form, so that such deposits must be regarded as made up of a vast number of crystals interlaced and united with each other, but still possessing pores or meshes which, though infinitely minute, interfere with the use of iron or other metallic vessels (lined with electro-precipitated copper) for chemical purposes. When copper is very slowly deposited from its solution by a long-continued but feeble current of electricity, it crystallizes in octohedra. If a large quantity of molten and liquid copper is allowed to cool slowly, it crystallizes in the rhomboidal form. With the intense heat of the oxy-hydrogen jet, copper boils like water, and throws out a vapour which condenses on any cold substance, and if examined by a magnifying glass, the deposit is found to consist of minute particles having a core of metallic copper coated with the oxide of the metal. Copper possesses great malleability, and may be beaten out into very thin leaves; when alloyed with zinc in the proportion of two of the latter to eleven parts copper, it forms the metal leaf called "Dutch metal," so extensively used in theatrical decorations, the ornamentation of toys, and certain kinds of gingerbread. The smell of copper is very peculiar, and, like cinnamon, the taste of this metal very much resembles the odour. Copper fuses readily with most of the metals, and affords several compounds or alloys which are of great use in the common arts of life.

The alloy of tin and copper called bronze has been made from the most ancient periods, and at least 600 years before the Christian era. It is stated that Athens and Rhodes each contained three thousand bronze statues. The latter place was celebrated for its colossal statue in bronze which reached to the height of the watch towers. The preparation of a perfectly homogeneous bronze appears to be one of some difficulty, and the proportions of tin and copper vary according to the use to which the bronze casting is to be applied. Thus for coinage it may contain from four to seventeen per cent. of tin. Occasionally, zinc is added in about the same proportion as the tin, so that the two together shall be from four to seventeen per cent. The bronze at the Royal Mint is cast into ingots, and, with many precautions, laminated between rollers; the blank pieces are then stamped out, weighed, adjusted, and impressed with the dies.

The coin of which Fig. 160, at the head of this chapter, is a sketch, represents the penny of the new bronze coinage which is to displace the old copper money, now become so imperfect as often to lead to a doubt of its legitimacy. The bronze money will consist of 95 parts of copper, 4 parts of tin, and 1 part of zinc in 100 parts of the mixed metals. The coins will be far thinner and, consequently, lighter than any of the old coins, as shown below:—

	Weighs in grains.	Measures in inches. Diameter.	Thickness.	Coins in one pound avoirdupois.
The penny . .	145·833	... 1·20	... 0·05550	... 48
„ halfpenny .	87·500	... 1·00	... 0·05100	... 80
„ farthing .	43·750	... 0·80	... 0·03846	... 160

so that each coin is about half the weight of its representative in the old

coinage of copper. The design on the coin possesses the important advantage of being a correct likeness of her Majesty at the present time (1860); otherwise it is without improvement, for there are to be found only the old emblems not even dressed in new ideas; but there is one alteration, of a strictly classical character, which deserves a passing word. If the inscription be read, it will be found to exhibit the word (usually spelt) "Brit." with a double "tt;" thus "Britt.," and for the following reasons. On the old Roman coins "Britt." occurs, and is believed by some numismatists to indicate that the coin was struck *out* of Rome, and arose from ignorance on the part of the coiners; whereas all coins struck *in* Rome at the same date exhibit the word spelt "Brit.;" and this latter was at the time the correct mode of terminating the word. At the present date it is necessary that the coin should indicate the Queen's supremacy over all the British possessions, and, in consequence, the abbreviation of the word "Britanniarum" must be treated in the same manner as other words in the classics are treated, and rendered (in its abbreviated form) plural by repeating the last letter; so that if the abbreviation be made by writing "Britan.," it must be written "Britann.," to indicate, as the word "Britt." does on our new coins, the whole cluster of the British Islands now denominated Great Britain.*

To convey an idea of the work of executing a new bronze coinage, it is only necessary to state that at this time there are estimated to be in circulation no less than 722,200 twopenny pieces (principally hoarded),

118,024,104 penny pieces,
266,855,297 halfpenny pieces,
102,966,564 farthing pieces,
16,438,176 half-farthing pieces (almost exclusively colonial),

504,284,141 copper coins,

besides many tons weight of tokens and false pieces.

In making any large castings the greatest uniformity in composition and purity must be attended to, and the account of failures in former years ought to enable contractors of the present day to avoid similar mistakes; thus, at the erection of the celebrated column in the Place Vendôme, the founder was completely ruined in consequence of his ignorance of the composition and properties of bronze. "The Chemist" of 1825 thus relates the story: "This column was erected by order of Buonaparte in commemoration of the victories of the French armies, and it was cast out of cannon taken from the Austrians and Russians in 1805. The whole weight of the different pieces of bronze composing it was 900,000 kilogrammes, or very nearly two million pounds. The contract for the performance of the

* To secure a perfect uniformity in the composition of the bronze, it is assayed by the resident Mint assayers before the alloy is coined, and a sample of each ton of coined bronze money is also assayed by Dr. Hofmann and Dr. Miller before it is allowed to go into circulation. Each coin is allowed to vary to the limit of $\frac{1}{10}$th part of its own weight above and below the standard weight given in the Table p. 277. The author begs to express his acknowledgments to Mr. George F. Ansell, one of the eminent chemists attached to the Royal Mint, for his courtesy in taking him through this most interesting public establishment, and also for the valuable facts given as above.

work was made with an iron founder, who undertook the whole, carving and all, for one franc a kilogramme. M. Darcet, the celebrated chemist, tendered some good advice on the occasion, which was rejected, and the contractor had a foundry built at a considerable expense. He employed a furnace for melting iron; and being ignorant of the fusion of bronze, he failed in his first attempts to cast the large pieces for the base of the column. At each operation he altered the proportion of the alloy by oxidizing the tin, the lead, and the zinc, the oxides passing into scoriæ, or being partly carried off by the heated air.

"He did not perceive this, and delivered the different pieces of different qualities, but all of them contained a greater proportion of copper than the bronze of the guns. When the column was about two-thirds finished, he found his supply of metal exhausted; and so sure had he been of having enough, that he had previously sold part of the ten per cent. allowed him for waste, under the idea that it would be more than sufficient. Being obliged to complete the work with the quantity of metal delivered to him, he was placed in a disagreeable situation. Under these circumstances, he endeavoured to cast the white metal obtained by reducing the scoriæ, and a quantity of old brass he purchased at a low price. The castings he obtained by mixing these materials were full of bladders and spotted with lead; they were at first of a dirty-grey colour, and afterwards became black. Such defective work could not pass; the labours of the contractor were put a stop to, his foundry was sealed up, and the man ruined." By dint of reclamations or appeals he procured the appointment of a commission to examine his accounts. The commissioners wished to know the proportions of the different metals in the guns delivered to him; but this point had not been ascertained, and, therefore, the most important element for coming to a correct conclusion could not be obtained. The weight of each piece of casting delivered by him was known; and by taking morsels from them all, and smelting them into one piece, an ingot was obtained representing the mean composition of the whole column.

After ascertaining this and knowing the general proportion of the alloys of which cannon are constructed, the commissioners agreed in opinion that the mean alloy of the column was equal to that delivered to the contractor. By analyzing the different pieces it was found that the large pieces of the pedestal contained only six per cent of alloy, while the small pieces of the shaft and column contained twenty-one. It was, therefore, evident that the contractor, not understanding the nature of bronze, had refined his alloy in the first instance by repeated meltings; and having thus diminished very much the total weight, was obliged to have recourse to the means already described. At the commencement of his operations, he had delivered the pieces with too much copper, and at the end with too little. The pieces were, after all, so badly executed, that 140,000 pounds of bronze were cut away by a sculptor, who was, moreover, paid 300,000 francs for his labour.

Speaking of the decoration of columns with bronze, there is the Nelson column, with its bronze Corinthian capital, and the four bronze reliefs representing the battle of St. Vincent, the battle of the Nile, the

bombardment of Copenhagen, and the death of the immortal Nelson at Trafalgar. There are also many bronze statues in London. Bell metal, of which "Big Ben" has been a most unfortunate example, is composed usually of seven-seven parts copper, twenty-one parts tin, and two parts antimony. English cymbals form very expensive additions to a set of instruments for a band, in consequence, it is said, of the large addition of silver, in order to give the peculiar clang of these instruments. The composition of Chinese gongs, cymbals, and tom-toms is very nearly the same as that of ordinary bell metal. It is a curious fact, that whilst steel is hardened by being cooled suddenly in water, copper, gold, silver, and bronze all lose their hardness and acquire a tough and malleable condition by being heated to a cherry red, and then plunged into cold water. M. Darcet was the first to show that brittle bronze vessels could be made hard and tough by heating to a cherry-red heat, and cooling them suddenly in water; and it was by attention to this operation that the ancients imparted such an edge and toughness to their bronze swords and spear heads.

Speculum metal, used by opticians in the manufacture of the concave mirrors of reflecting telescopes, requires great care in the casting; it is usually composed of about sixty-seven parts copper and thirty-three of tin, with a little arsenic. The author once assisted the late Mr. Cuthbert in casting some of his speculums for his celebrated telescopes. The metal was cast in a crucible by the heat of a furnace, such as that described at p. 251, and when liquefied, was poured into iron moulds, which were then covered up with sand and ashes, in order that the cast metal might cool slowly. The most useful alloy of copper is, perhaps, that which is included under the generic term brass, and consists of copper, zinc, lead, and tin, in different proportions according to the use to which it is to be applied. Various arbitrary names have been given to this alloy, and it has been termed mosaic gold, Prince Rupert's metal, pinchbeck, Mannheim *gold*, Bath metal, tombac, Dutch gold, &c. Brass may contain from 60 to 92 per cent. of copper, from 5 to 35 per cent. of zinc, from one-half to 3 per cent. of lead, and from a quarter to 3 per cent. of tin.

A very important alloy of copper used for sheathing vessels, termed Muntz's metal, and remarkably soft and malleable, is composed of 16 parts copper, and 10⅔ zinc; this alloy has a golden appearance, and contains less zinc than mosaic gold, which, with the same proportion of copper, is alloyed with about 17 parts of zinc.

The Chinese pakfong, tutenag, German silver, and electrum owe their whiteness to the presence of the metal nickel, and, like brass, the proportions of their ingredients—viz., copper, nickel, zinc, with occasionally a little lead or iron—are variable. Thus the pakfong contains about 31⅓ per cent. of nickel, whilst the ordinary "German silver" contains from 20 to 25 per cent. Spoons made of this alloy consist usually of copper 50, nickel 25, zinc 25 parts.

Unalloyed copper is used for innumerable purposes in the arts and manufactures; plates, &c. for engravers, domestic utensils, kettles, *scuttles, urns*, coinage, sugar-refining apparatus, brewers' coppers, dis-

tillers' stills, dyers' vats, marine powder-magazines, sheathing of ships, soda-water machinery, and culinary and confectionary vessels; the latter are usually coated inside or alloyed with tin, in order to prevent the poisonous effects of copper. The tinning of copper vessels used in cooking should be as scrupulously attended to as it is in India, where all the cooking vessels are made of this metal or brass, and are regularly coated with tin at stated intervals or sooner if necessary. Pins are tinned by the wet process, and are coated with the metal by boiling them with water, bitartrate of potash, and finely-divided tin. In Russia (as it used to be in England in the mediæval period), the roofs, domes, and cupolas are frequently covered with copper and sometimes gilt, of which we give an example in the next cut, representing the bell towers and famous bell of Ivan Veliki at Moscow.

Fig. 168. The Bell Towers with gilt copper cupolas, and famous Bell of Ivan Veliki at Moscow.

Experiments with Copper.

First Series.

The assay of copper ores demands a considerable acquaintance with the nature of fluxes, and the manipulations connected with furnaces, the fuel, the crucibles, the regulation of the heat, &c. The ores are usually divided into three classes—

No. 1 includes ores such as the red oxide of copper, the black oxide of copper, the green carbonate of copper, the blue carbonate of copper, &c. &c., which, with the exception of a little iron, contain no other metal but copper, and are quite free from sulphur and arsenic. Such ores, after being powdered, may be mixed with at least three times their weight of black flux, prepared by throwing into a red-hot crucible a mixture of one part nitre and two of crude tartar. The furnace, such as that described at p. 251, must be lighted some time beforehand, and should be, with the crucible, quite hot. The mixture of ore and black ore is then thrown in, so that about one-third of the red-hot crucible is filled, leaving the remaining space for the materials to swell and puff up, and it is usual to spread a thin layer of black flux on the top of the mixed ore and flux. The cover of the furnace is left off until the pasty mass is in a state of tranquil fusion, when the furnace is closed and the heat urged to the utmost for about twenty minutes; the glowing crucible is then removed, gently tapped on a dry and warm brick, where it is allowed to stand till cold, or the contents are at once poured into a conical iron mould. The impure metallic button of copper called the *prill* is found at the bottom of the crucible and mould, and may be examined, if necessary, by the humid process of analysis described at p. 284. In order to collect every particle of copper, it is usual, when assaying very pure copper ores of this class, to fuse them first in conjunction with sulphur, and to assay according to the method belonging to the next division.

No. 2, ores containing only copper, iron, and sulphur, such as copper pyrites, copper glance, vitreous copper, red ruthite, &c. The pulverized ore is mixed with its own weight of borax (previously dried and powdered), and melted in a crucible at a moderate heat. The contents are then poured into a proper mould, and when cold the sulphide of copper called the "*matt*," is found at the bottom, and may be easily separated by a hammer from the slag which contains the earthy matters called the *gangue*.

The "matt," regulus, or button, is then powdered (being very brittle, in consequence of its combination with sulphur), and thrown into a crucible arranged in a slanting direction, and placed in a furnace where the heat is kept as low as possible, and the mouth of the crucible well supplied with air; these conditions are fulfilled by using a properly-constructed roasting furnace like that depicted in the next cut, although, where expense is an object, an ordinary open fireplace would, (with proper care) answer the same purpose.

As the roasting proceeds the heat may be gradually raised, and when the odour (like that of a burning sulphur match) can no longer be perceived, the crucible may be shifted to a wind furnace, and brought up to a full white heat in order to decompose the sulphates and drive off the last atom of sulphur. Sometimes a little carbonate of ammonia is stirred in before exposure to the white heat. The roasted ore is finally mixed with three and a half times its weight of black flux, and being covered with a stratum of powdered fused borax, called glass of borax, it is strongly heated in a wind furnace for about half an hour, taken out, cooled, and broken, when the button of copper is found at the bottom as usual, and may be cleaned by hammering on the anvil and gently rubbing it with the leather gloves usually worn by

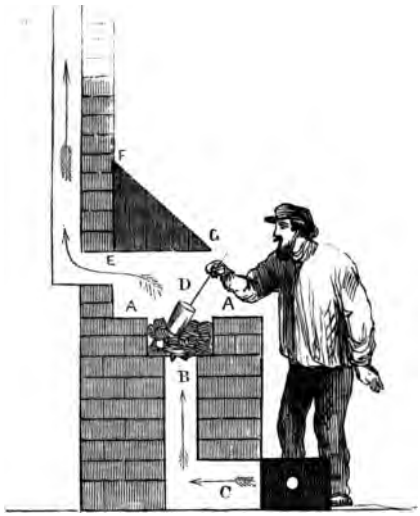


Fig. 169. Roasting Furnace. A A. A square cavity in brickwork, with small grate at B, to which air passes from the opening C, closed at pleasure by a door and register. D. The crucible containing the powdered "matt," which is kept at a very low heat, and occasionally stirred with a steel rod; the sulphur is oxidized and carried up the chimney at E, and the whole is covered with a hood of sheet iron, F G.

those who perform many crucible operations. The wind furnace will be described in another part of this work.

Third class copper ores, such as grey copper ore, tennantite, white copper ore, &c., containing the sulphides of other metals and arsenic, are first powdered and fused with borax to obtain the "matt," which is then powdered, and very slowly and carefully roasted, to prevent the

fusion and agglomeration of the particles. When arsenic is present, it is usual to mix in a little powdered charcoal after the first roasting, and then to raise the crucible to a bright red heat. The roasted "matt" is then fused, as already described, with black flux or glass of borax, and the button of copper, containing various other metals, is placed on a cupel of bone earth in the muffle with a certain proportion of pure lead, and cupelled in the manner described at p. 223. The lead removes the other metals, and, being oxidized with them, sinks into the cupel, whilst the copper remains behind as a little bead or button, which ceases to rotate, and suddenly brightens up when the process is complete. The cupel is removed, cooled, and the bead of copper picked off, gently hammered, rubbed, and weighed. In these metallurgical operations *par la voie sèche*, practice truly and only makes perfect, and each assay should be repeated at least twice.

Second Series.

Copper is analysed in the humid way, *par la voie humide*, by dissolving, say twenty grains (cut off the sheet, wire, or ingot), with nitric acid in a flask provided with a long neck, or one partly closed by a funnel. If any antimony or tin are contained in the sample, they will be left behind as insoluble teroxide of antimony and binoxide of tin, and they may be further precipitated by evaporating away the greater part of the excess of acid and diluting with water. By filtering, these oxides are separated, and may be collected, weighed, and examined by the tests described under the respective chapters on these two metals; although it may be mentioned here that tartaric acid will dissolve out the oxide of antimony, and leave the oxide of tin behind.

The solution contains the copper with any silver, lead, zinc, iron, or arsenic with which it may have been contaminated. The silver is precipitated by the addition of a few drops of hydrochloric acid, and, being allowed to settle, the solution, now containing the copper, lead, zinc, iron, and arsenic, is washed away carefully, and the chloride of silver collected, dried, and weighed. The solution mixed with the washings from the chloride of silver is now precipitated with sulphuretted hydrogen, and being kept slightly acid, is gently warmed, filtered, and the precipitated sulphides of copper, lead, and arsenic collected and washed. The iron and the zinc are the only metals now left in the solution, which is evaporated to a small bulk with some nitric acid and treated with excess of ammonia, which throws down the sesquioxide of iron; after filtration to separate the latter, sulphide of ammonium is added to precipitate the zinc. The precipitated sesquioxide of iron is washed, dried, and ignited, and the sulphide of zinc may be converted into the more permanent oxide of zinc before it is weighed and estimated. The sulphides of copper, lead, and arsenic left upon the filter must be kept as much as possible from contact with the air during the washing, and this may be managed by putting the glass and funnel under a gas jar kept full of coal gas by holding an india-rubber pipe connected

with the gas fittings under the jar, and occasionally allowing the gas to escape (Fig. 170). The nose of the analyst will inform him when it is escaping from the edge of the jar. If the mixed sulphides, and especially the sulphide of copper, is not defended from the oxidizing action of the air, it is rapidly converted into sulphate, and washed away and lost during the edulcoration of the mixed sulphides. A little hole is now made in the filter, on which the sulphides remain, and they are washed off into a flask by a solution of sulphide of potassium, for the purpose of dissolving out any arsenic that may be present. The solution may be decanted off, and the sulphides washed by decantation. They are then treated with weak nitric acid, and the solution is filtered and evaporated to dryness with sulphuric acid. This latter separates the lead as the insoluble sulphate of lead, which is collected, dried, weighed, and estimated in the usual manner, after, of course, treating the dry residue with distilled water. Copper only now remains in the washings in solution, and this is precipitated by the addition of caustic potash, which throws down the hydrated oxide of copper of a blue colour, changing to a dense black powder when the solution containing the precipitate hydrated oxide of copper is boiled. The black powder is collected, washed, dried, and scraped off the filter on to a piece of glazed paper, the filter is burnt away in a porcelain crucible, and then the black powder is placed in and also ignited, and finally weighed. Every 40 parts of the black oxide of copper are equivalent to 32 of copper. The oxide of copper must be weighed whilst hot, as it absorbs moisture with great rapidity.

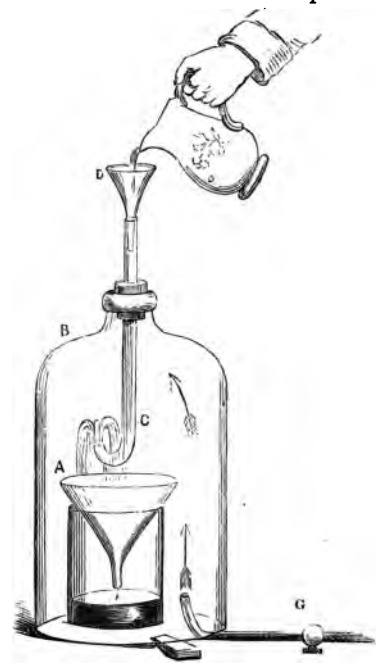


Fig. 170. A. Funnel and filter containing the sulphide of copper, &c. B. Gas jar fitted with a cork and glass tube in neck; the tube is bent round at c, so that the coal gas may not escape. D. The funnel by which the water is poured in to wash the sulphide of copper, and by turning the beaker round that supplies the funnel, every part of the filter may be washed. G. Gas-pipe connected with the coal-gas fittings. The arrows denote the entry of the gas.

Third Series.

The equivalent or combining proportion of copper is 31·7 and it unites with oxygen in various proportions, as follows:—

Suboxide of copper	Cu_2O
Protoxide, or black oxide . . .	CuO
Binoxide	CuO_2
Cupric acid	

The suboxide is made by heating a mixture of five parts of the black oxide of copper with four parts of copper filings, in a close crucible, to a full red heat; or by the wet process, by first boiling some syrup with a little dilute sulphuric acid to convert the cane into grape sugar, and then adding a solution of sulphate of copper with excess of caustic potash to redissolve the precipitated oxide and form a violet-blue solution. On boiling this solution of copper for some time, the suboxide gradually deposits and presents a crystalline form with a fine red colour. This combination is found in nature, and is called by mineralogists red copper ore. Black oxide of copper is obtained by dissolving pure copper in nitric acid, evaporating to dryness, and igniting the residue in an earthen crucible until no more red nitrous fumes are visible. The process occupies some time, and the oxide should be stirred now and then with a copper rod. Binoxide of copper and cupric acid are combinations which are only interesting to the chemist. The suboxide and the protoxide of copper are both employed in colouring glass; the former imparts a red colour, and the latter a blue or green colour. The protoxide, or black oxide, forms with sulphuric acid that most valuable salt called "blue vitriol," or sulphate of copper, CuO,SO_3HO+4 Aq., which is employed so extensively in electrotyping and other useful arts, likewise in medicine, and also in agriculture for the purpose of steeping grain, before it is sown, to prevent smut. Sulphate of copper is sold at such a very cheap rate, that it is never worth while to make it on the small scale. Nitrate of copper is obtained by dissolving the black oxide, or metallic copper, in nitric acid, and evaporating the solution till a pellicle forms. The crystals are represented by the following formula: CuO,NO_5 with 4 or 6 Aq., according to the temperature at which it crystallizes.

The hydrated oxide of copper or oxide of copper united with a definite proportion of water, $CuO,2HO$, is obtained from a solution of nitrate of copper by the addition of small quantities of caustic lime until the green precipitate is no longer thrown down and the solution becomes colourless. The precipitate is then filtered and washed, and, when nearly dry, from eight to eleven per cent. of powdered caustic lime is well incorporated with it, when the green colour changes to blue, forming the well-known pigment termed blue verditer.

Sulphate of copper unites with ammonia, and produces magnificent blue crystals, $CuO,SO_3,2NH_3HO$. The large show-bottles placed in the windows of the chemists and druggists have generally one of their number filled with a dilute solution of copper to which a slight excess of ammonia has been added.

Fourth Series.

Pure copper is obtained by decomposing a solution of pure sulphate of copper by the voltaic current, as in the ordinary process of electrotyping. The manipulations of this art have been so elaborately explained by Napier and Walker, and also in the "Boy's Playbook of Science," that it is almost unnecessary to mention them here; but as young persons do not generally possess many books, and are sometimes restricted by their finances to one, we give an easy method of conducting the process.

In the centre of a stoneware pan, or square wooden box well dovetailed and made water-tight, without nails, and nearly filled with a

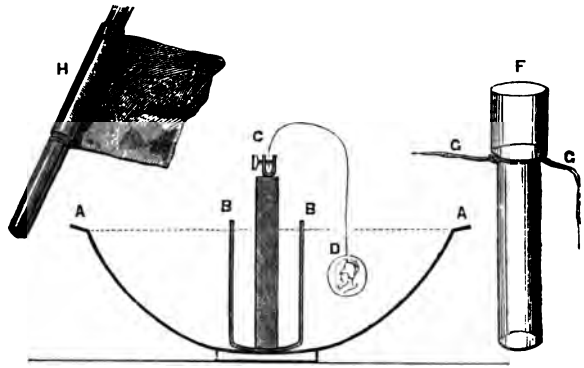


Fig. 171. A A. Basin containing the solution of sulphate of copper. B B. The porous cell, containing dilute sulphuric acid. C. Amalgamated zinc rod and binding screw attached to wire and medal D. F. Porous cell, made with a lamp-glass closed at small end by bladder and wire support G G, to prevent the membrane touching the bottom of the pan containing the solution of sulphate of copper. H. Brown paper porous cell, prepared by rolling paper of the required length at least three times round a ruler, and closing the sides and bottom with sealing-wax after the bottom is folded in.

strong solution of sulphate of copper, place a porous cell containing a rod of amalgamated zinc surrounded with a mixture of one part strong sulphuric acid and twenty parts of water. Round the top of the zinc rod is wound one end of a length of thin copper wire, and the other is attached to the seal or medal, previously well blackleaded and polished. If a medal is used, the back should be imbedded in gutta-percha or covered with wax, and the wire twisted round the rim, as the deposit of copper is not required at the back, and might, indeed, spoil the medal by preventing its subsequent removal from the electrotype cast. Very little blacklead should be used with a medal, as it stops up the fine lines; and sometimes a little sweet oil, or solution of wax in turpentine is rubbed over it so as to prevent the deposited copper sticking to and spoiling the medal. If an impression in sealing- or candle-wax is used, this must be well blackleaded and polished on one face, and twisted round with the thin wire, which is placed in good

conducting communication with the blackleaded surface. The medal or cast is then placed into the solution of copper, and the whole left for twelve hours, when the copper is precipitated over the surface of the medal or cast, of which it takes an accurate copy in intaglio. From the intaglio may be taken any number of other electrotype impressions in relievo. The porous cells may be either unbaked earthenware, brown paper rolled up and sealed at the bottom and sides, or a lamp-glass closed at one end with wet bladder.

Fifth Series.

Copper not only combines with oxygen, but also unites with the two permanent gaseous elements hydrogen and nitrogen. According to Wurtz, the former has a formula of Cu_2H, and the latter, by the experiments of Schrötter, is ascertained to have the composition of Cu_6N. This compound, as might be supposed, has a tendency to explode, and appears to separate into its elements with sudden energy at a temperature of 509° Fah. Copper filings, or, still better, copper leaf placed in chlorine gas, is attacked with rapidity, and, if heated in chlorine, takes fire. Dutch metal, which contains zinc, burns immediately it comes in contact with chlorine. Copper forms in this way the anhydrous chloride of copper, CuCl, which may be converted into the subchloride, Cu_2Cl, by heating it to redness in a current of chlorine gas.

A very pretty green colour, passing to shades of blue, and assuming a variety of tints between blue and green, is displayed on the ceiling of a room in magnificent waves and miniature billows, which appear to roll over each other in the beautiful experiment called "the fire cloud." The apparatus for the performance of this experiment consists of a very strong copper bottle furnished with a good brass stopcock, pipe, and jet, and capable of being fitted to a condensing syringe.

To prepare the experiment, a solution of chloride of copper in alcohol or methylated spirit, in the proportion of an ounce of the chloride of copper to a quart of the spirit, is filtered or decanted quite clear from all undissolved crystals, and poured into the copper bottle so as to fill about one-half of its volume; the bottle must be scrupulously clean, as any fine solid particles getting into the jet completely destroy the success of the experiment. After the solution is poured in, the stopcock and copper pipe, passing to within an eighth of an inch of the bottom, are screwed in and the hand-pump attached. Air is now pumped in till the valves of the pump refuse to work, and being removed, after turning off the cock, a jet with an orifice of about one-twentieth of an inch is screwed on. Before allowing the alcoholic solution to escape, it is better to place the copper bottle in a pail of boiling water until thoroughly but gently warmed, when it may be placed in a ring holder attached to the body by a strap for the convenience of directing it at any angle, and a torch being now held to the ceiling of the room, which should be plaster, and about ten or twelve feet above the head of the operator, who may wear an old cap or hat, the cock is *turned*, the alcohol then takes fire on the ceiling, and being continually *supplied with* a finely-divided jet of spirit, which is gently moved over

a space of about ten feet square, it produces the beautiful undulating and delicate blue-and-green coloured flame already described.

The oxychloride of copper ($CuCl,3\,CuO,4\,HO$) is an important pigment, called "Brunswick green," and may be prepared by wetting sheets of copper with hydrochloric acid and exposing them to the air, and again repeating the wetting and exposure until the whole of the copper is decomposed. This pigment is one of the cheapest green colours sold, and is used very extensively for out-door purposes. The natural oxychloride of copper is called atacamite.

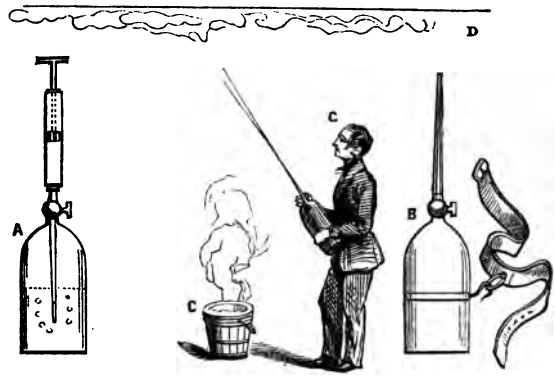


Fig. 172. A. Section of copper bottle with pipe, condensing pump, and stopcock. The bottle is half full of the alcoholic solution. B. Copper bottle ready for use, with the jet screwed on and attached to a leathern belt by a ring and hook. C. Pail of boiling water. G. Use of the copper bottle, from which the jet of alcohol escapes to the ceiling D, where a torch of tow dipped in spirits of wine is held for a few minutes, till it takes fire properly.

Iodine and bromine both unite with copper, forming proto- and subsalts like the chlorides. Fluorine also combines with this metal.

Sixth Series.

If a lump of copper pyrites is placed in a solution of chloride of barium and connected with a weak voltaic current, it is gradually changed into sulphuric acid (which unites with the baryta and forms sulphate of baryta), peroxide of iron, and sulphide of copper, or grey copper ore. The sulphate of baryta is obtained from the oxidation of the sulphur in the pyrites, which liberates the iron subsequently oxidized, and leaves the sulphide of copper.

Seventh Series.

A Florence flask filled with copper turnings, and then some roughly-powdered sulphur sprinkled in so as to be well distributed through them, affords an interesting example of combustion carried on without the presence of oxygen. When the heat of a spirit lamp is applied to the flask and its contents, they soon begin to glow with a red heat, and the copper unites with the sulphur and forms the black and easily-powdered subsulphide of copper (Cu_2S). This black matter, boiled with dilute nitric acid, is decomposed, a small portion of the sulphur is oxidized and forms sulphuric acid, but the larger portion collects in small lumps, which may be separated by filtration, and present on combustion the usual indications of sulphur, whilst the blue colour of the solution of copper, in which a zinc or iron plate can be placed to precipitate the metal, affords an instructive example of a simple chemical analysis in which the copper is again recovered in its metallic state. The subsulphide of copper exists in nature, and is called "copper glance;" and the sulphide (CuS) is known in mineralogy as "blue copper." Copper pyrites is a mixed sesquisulphide of iron and subsulphide of copper (Fe_2S_3,Cu_2S), and the greater proportion of copper is obtained from this mineral, which assumes, in one of its species, the most lovely appearance of azure blue and other colours, and is called from that circumstance "peacock copper ore."

Eighth Series.

Artificial malachite, or bibasic carbonate of copper is prepared by precipitating a saturated hot solution of sulphate of copper with one of carbonate of potash; the green precipitate gradually collects, becomes granular, and after being well washed and dried, is called "verditer green" or "mountain green;" when unmixed with foreign matters, it has the same composition as malachite, $2\,CuO,CO_2,HO$.

Ninth Series.

A little nitrate of copper in crystals slightly damped and wrapped up in tin-foil produces a most energetic action, with the evolution of nitrous acid fumes, and an exchange of places occurs, by which the tin is united with oxygen, and the copper precipitated in the metallic state. It is stated that the production of the nitrous acid fumes is accompanied with the production of light, but the author has never yet seen that effect produced, although it is quite possible to suppose that it might do so occasionally, *or* if performed in an atmosphere of pure oxygen gas.

Tenth Series.

The double sulphate of copper and potash is prepared by neutralizing a solution of bisulphate of potash with hydrated oxide of copper, and then evaporating the liquid till a pellicle is formed and the salt crystallizes. When heated on a piece of platinum foil, it melts, and if

allowed to cool, assumes a green and then a light-blue colour, and just when it might be expected that the fused salt would become solid, a sudden movement is seen, and decrepitation commences, which is very distinctly audible, and the whole falls to powder. When the experiment is made in a porcelain capsule, the same effect occurs, but slower, and if the cup containing the fused salt is placed on a sounding-board, the almost musical sounds emitted whilst the crystals are breaking up are very curious. Some alteration in the cohesive power of the molecules of the crystals, brought about by unequal contraction, appear to produce the effect, which is worthy of more careful examination.

Eleventh Series.

Paper prepared with a pulp containing the phosphate of copper is slightly blue or bluish-green, and is recommended by Messrs. Glyn and Appel as a preventive to forgery by the anastatic process. To show the principle, a sheet of paper or blank cheque may be moistened with some dilute nitric acid containing a little solution of copper, and when this is laid upon the zinc plate, as in the ordinary process of anastatic printing, it undergoes an immediate change; the zinc precipitates the copper, and if the cheque and zinc plate are passed under the roller, the paper is blackened by the precipitated copper, and adheres so firmly to the zinc plate, that it cannot be removed without destroying it, and hence it was stated that, supposing a forger were to attempt to take an imitation copy of a note printed on this prepared paper, he would be punished at once by the loss of his property, provided he did not possess the proper amount of chemical knowledge to extract the copper before attempting to take the anastatic copy.

Twelfth Series.

Succinate of copper heated in a glass tube till the decomposition is complete, and then hermetically sealed like the pyrophoric lead described at p. 252, takes fire spontaneously when shaken into the air, and very pretty results are obtained by dropping the finely-divided copper alternately into bottles filled with oxygen and chlorine.

Thirteenth Series.

The tests for copper afford results which cannot be very easily mistaken. In the first place, the solutions of this metal, even when very dilute, present a blue colour, which is rendered further apparent by evaporating a few drops on the lid of a white porcelain crucible. The addition of ammonia causes the production of an intense blue colour.

Ferrocyanide of potassium affords a distinct brown tint in solutions of copper, even when they are diluted to the highest degree. A gallon of water containing one grain of copper in solution would afford a very distinct brown cloud with the ferrocyanide of potassium, and the dilution might be carried higher if the solution is first evaporated in the lid

of a porcelain capsule before applying the test. The precipitated ferrocyanide of copper is insoluble in acids. Zinc, iron, tin, lead, all precipitate copper; perhaps a zinc plate affords the most visible results, because the difference of colour is so very marked, and the oxide of zinc is white.

In testing bread supposed to contain copper, a zinc plate will detect a very minute quantity, and all that is necessary is to acidify the bread with dilute pure sulphuric acid, and leave the zinc therein. The deposited copper may be scraped off, dissolved, and tested in other ways.

Sulphuretted hydrogen throws down a black precipitate of sulphide of copper.

Ammonia precipitates and re-dissolves the oxide of copper, producing an intense blue solution.

When an almost invisible and very minute quantity of copper is precipitated on an iron plate, it may be detected by moistening the iron with a solution of chloride of ammonium, and holding it in the flame of a spirit-lamp, when a beautiful green colour is obtained.

Mr. Henwood gives a very interesting anecdote, showing the application of this simple test: "In the Great Wheal Towan Mine, Cornwall, they had for years been following a string of quartz, accompanied by a small quantity of rich copper ore; the walls of this lode were so hard as to deter them from commencing operations on them for cross cuttings. At length a man, *to preserve his tobacco-pipe*, made a small hole in which he placed it, when to his great surprise a quantity of water of a black colour issued, which he tried by the usual miners' test—viz., wetting his fingers in the substance, and applying them to his candle—immediately the *colour of the flame* gave unmistakeable signs of copper. This fortunate discovery laid the foundation of one of the largest fortunes that Cornwall can boast."

A dilute solution of salt attacks copper with considerable rapidity, and when pickles have been foolishly boiled in badly-tinned copper vessels, or copper coin placed in the vinegar to impart a fine green colour to them, a zinc or iron plate will readily separate the copper, if digested for some time with the pickles. The action of a weak solution of salt on copper is well illustrated by the destruction of the copper sheathing of ships, which sometimes disappears with astonishing rapidity.

The corrosive power of the chloride of sodium contained in sea-water appears to be greatly increased with the voltaic action set up by the different mechanical conditions of each separate plate of copper. A voltaic circle is commonly made with a plate of zinc and one of copper immersed in dilute sulphuric acid, being two dissimilar metals placed in a fluid which acts rapidly upon one of them. Two plates of zinc, prepared under precisely circumstances, and immersed in dilute acid, will however afford a feeble current of electricity, which may be rendered apparent by means of a delicate galvanometer needle, such as that described in the "Boy's Playbook of Science," showing that, if there is the slightest physical difference between the plates, it is suffi-

cient to set up a voltaic action in which one plate is more rapidly attacked than the other. It is not difficult to suppose that ships may be coppered with plates that have been made from different samples of copper, and rolled at one or more mills; under these circumstances there is a specific chemical and mechanical variety in each sheet of copper, and directly the ship is immersed in sea-water a series of voltaic currents are set up which greatly promote and increase the chemical action; and no doubt frequently cause the copper to dissolve more quickly, although on analysis the sheathing may prove to be made of pure and good metal.

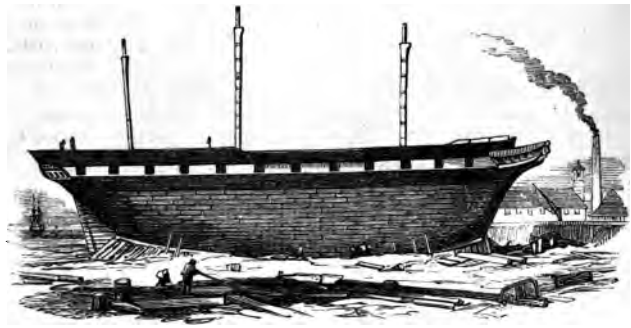


Fig. 173. Sheathing a Vessel with Copper.

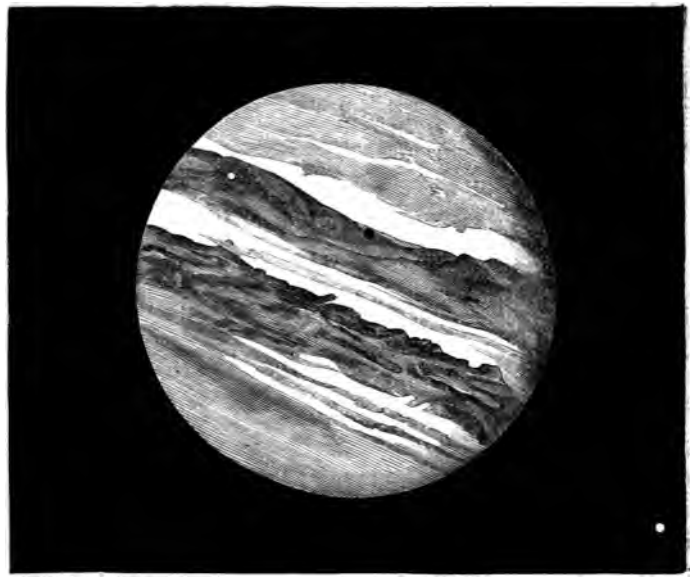


Fig. 174. The Planet Jupiter. (Warren De La Rue.)

CHAPTER VIII.

TIN, ANCIENTLY-CALLED JUPITER. 4

The character represents the thunderbolts of Jove.

It has been truly remarked that the spirit of inquiry is a *restless* one, and never slumbers; this greedy desire for knowledge incessantly urges the mind of man to ask questions which time and observation only can answer, and certainly one of the favourite queries of those who study mineralogy is the ever-recurring one of "How were the minerals deposited in the cracks or fissures of the earth?" In the chapter on gold, p. 177, it has been explained that, according to the "Plutonic theory," the crust of the earth has been disturbed by the heaving up of the melted and intensely-heated mass of rock from below, which, pushing its way upwards, has displaced and upheaved certain strata, and possibly produced, by subsequent cooling and contraction, the cracks and fissures

alluded to. In the process of time—not to be counted by days or years, but by centuries—certain solutions of earthy and metallic substances, saline and mineral waters, have been conveyed into and slowly passed through these large receptacles, in which crystallization has been set up, and in consequence of the slowness of the deposition of crystals, like those of quartz, crystallized silica or sand of remarkable hardness has been produced. Crystallization has probably been assisted further by electrical attraction, and it is quite possible to conceive that the variable composition of the walls of these cracks or places, now filled with solid matter and called lodes, might have set up feeble currents of electricity, which the late Mr. Crosse, in his original experiments, has shown will bring about the most singular changes of physical form, whilst Becquerel has imitated nature, and produced by slow electric action the sulphides of silver, copper, lead, and tin in the most perfect and beautiful crystalline forms.

Dr. Noad, in his most complete "Manual of Electricity," says: "More recently the weak actions to which Becquerel's attention has been more particularly directed, are those which commence as soon as the rocks, the metallic and other substances which occupy veins and beds, come into contact with the *mineral waters* that rise from all parts of the earth's interior. *Time* then becomes an element in the growth of the crystalline substances formed." The following experiments were made by Becquerel:—

First Series.

A plate of amalgamated zinc surrounding a copper wire was plunged into a solution of silica in potash. After a fortnight's action, very small regular octohedral crystals of siliceous oxide of zinc were formed on the zinc plate.

Second Series.

A lead-copper arrangement was substituted for the zinc-copper, when anhydrous crystals of oxide of lead were deposited on the lead plate.

Third Series.

Fragments of the mineral galena or sulphide of lead were left for *several years* in solutions of chloride of sodium and sulphate of copper (both of which solutions would occur naturally in the earth, either as brine-springs or copper-water); the following were the products obtained by this slow action, and they were deposited either on the galena or on the bottom and sides of the vessel. No. 1. Chloride of sodium or common salt in cubes, cubic octohedrons, and even in octohedrons having great transparency and very definite forms. No. 2. Chloride of lead in cubes, and needles slightly yellowish and of a very perfect form. No. 3. Sulphate of lead in cuneiform octohedrons, much modified, precisely resembling the crystalline sulphate of lead of Anglesea. No. 4. Chlorosulphate of lead in needles. No. 5. Basic chloride of lead in microscopic crystals, disconnected here and there throughout the whole

product. No. 6. Sulphuret of copper, black, without an appearance of crystallization. The whole of these substances covering the piece of galena gave it the appearance of a specimen from a mineral vein.

Fourth Series.

A voltaic couple formed of a piece of galena surrounded by a platinum wire placed in a saturated solution of common salt, and sulphate of copper diluted with three volumes of water, gives rise to the formation of a considerable quantity of crystallized chloride of lead in cubes, without any other product.

Becquerel thinks that these reactions take place in nature; rain water coming in contact with mineral masses and veins formed of metallic combinations, becomes charged with chloride of sodium and sulphate of copper, arising (as it does at the present time) from the decomposition of copper pyrites; these solutions, once in contact with galena, react upon it weakly, and give rise to those combinations mentioned in the third experiment of Becquerel; the action is, indeed, progressive, and reminds one, in its succession, of the old "Joe Miller" of the parson who told the clerk, who told the sexton, who tolled the bell, one event succeeding the other with the utmost regularity, and only requiring time for its fulfilment.

Dr. Golding Bird has also suggested an arrangement by which nature's processes have probably been still further imitated, and crystals of metallic copper, suboxide of copper or red copper ore, and oxide of zinc produced:—

"A glass tube, open at both ends, about half an inch in diameter, and three inches in length, is closed at one end by means of a plug of plaster of Paris about one-third of an inch in thickness. The tube is filled with a moderately diluted solution of nitrate or chloride of copper, and placed inside a cylindrical glass vessel nearly filled with a weak solution of potash or soda. The leaden leg of a compound lead and copper arc is plunged into the outer cylinder, and the copper leg into the tube. The lead slowly dissolves in the alkaline solution, and electric action is set up; the current traverses the plaster of Paris partition, and the oxide of copper (precipitated by the slow admixture of the alkaline solution with the copper salt) is reduced partly to the metallic state and partly to suboxide, both of which crystallize on the negative copper leg of the arc. If a solution of oxide of zinc in caustic potash be substituted for the uncombined alkali in the larger vessel, a very elegant deposit of oxide of zinc takes place in about eight or ten days, on the lead or positive plate, while fine crystals of copper and suboxide are deposited on the copper or negative plate." The detail of these experiments is sufficient to indicate to the student that King Pluto need not be made responsible for the mineral deposits, although he probably paved the way for their production by causing those cracks, rents, and great voltaic cells in the earth which were subsequently filled by the agency of that potent solvent water which "Old Neptune" is supposed

to rule over. We cannot conceive Pluto and Neptune to be antagonistic, as fire produces water, and *vice versâ*—they were firm and good allies, and, like the French and English combination, were great in their respective specialities, and in the course of time, no doubt, performed works which an all-bountiful Providence has made subservient to the wants of man.

Professor Hunt says, however, we must not too hastily decide upon the agency of electricity being the only cause of the production of mineral veins, "The probability being, that a set of physical forces acting on the surfaces of the material particles, which are as yet only dimly seen by the eye of science, will be found to be the causes regulating the effects under consideration."

"It is certain that in Devon and Cornwall there are distinct indications of the influences excited by two dissimilar rocks, in producing the formation of the metalliferous minerals. It is evident that *a main line of direction* is observed by mineral lodes, and usually the direction of lodes containing the ores of lead is nearly at right angles to that of the copper and tin veins in the same district. In the lead districts of Wales and of the north of England we find the ores of this metal commonly occurring in the *limestone* bands, and appearing only slightly, if at all, in the sandstone and shale strata, associated with the limestone. There are, however, districts, and extensive ones, in which the lead occurs in the *sandstone*, and not in the limestone, and there are some in which the preference appears to have been given to the shales. This is strikingly shown at the Grassington and at the Cavanley mines. These facts prove to us that some conditions, beyond those which are dependent upon the chemical constitution of the rocks, are to be sought for."

These preliminary remarks upon the probable deposition of the minerals have been made, because tin, the metal now under consideration, is rarely found alone, but is more or less associated with ores of copper and zinc, also with wolfram, arsenical pyrites, &c. The walls of the lode which contain tin are frequently granite, that being the rock in which the veins most abound, but it is likewise disseminated in clay and chlorite slate, gneiss and other metamorphic rock. When procured from veins it is called "mine tin," but it is obtained in large quantities from alluvial deposits and drift, like gold; indeed, it is, in searching the stream works for tin, that the vigilant Cornish miners sometimes discover little particles of the precious metal gold, which are his perquisites, and usually preserved in a quill carried about his person, and called tinner's *prilly*, or particles. Tin ore obtained from the stream works is termed "stream tin;" it is a binoxide of tin, SuO_2, and is usually called tin-stone. The hardness of this mineral is taken advantage of; and when powdered, it is used for polishing metals, glass, &c., under the name "*putty powder*." It was the ores of tin that attracted the Phœnician traders to ancient Britain, of which they related the most fearful stories, in order most probably to keep other persons from visiting the barbarous island. The ores of tin are called—

Tin pyrites, or sulphide of tin .	Containing tin, copper, iron, sulphur, and earthy matters, and sometimes zinc.
Tin-stone, or binoxide of tin, and Wood tin, or Cornish tin ore . .	Containing tin, iron, and oxygen, with a little siliceous matter.

Although a certain quantity of tin is brought from Asia, and especially from the Island of Banca, in the Indian Archipelago, belonging to the Dutch government, the greater proportion is obtained from Cornwall, which has always been celebrated for that metal from the earliest historic periods. The Romans obtained tin from Britain, in order to form their bronze helmets, weapons, shields, &c.; and in certain parts of Cornwall there still remain the mouldering remains and *débris* of old furnaces, and slag or dross. The old furnaces are curiously termed "Jews' works," and the heaps of slag or melted earthy matter derived from the smelting of the tin ore "Jews' attal." There is one remarkable heap, called "Attal Saracen," as if tin had been melted at one time for people who traded with the Saracens, or that the metal had been made for those who warred with these brave descendants of Ishmael. The metal tin is mentioned by Moses, and it was from Cornwall that the Phœnicians obtained this metal which, with copper, formed the Assyrian and Egyptian bronzes. It is supposed that St. Michael's Mount and Looe Island were the ancient shipping ports for the tin obtained round St. Austie, and mentioned by Diodorus Siculus, the famous historian and contemporary of Julius Cæsar and Augustus. Diodorus says, "It is something peculiar that happens to the islands in these parts lying between Europe and Britain; for, at full tide, the intervening passage being overflowed, they appear islands; but when the sea returns, a space is left dry, and they are seen as peninsulas." In Mount's bay the tin-stone has been found in beautiful glassy white and limpid crystals; the author recollects, when a boy, being promised specimens of these so-called "Cornish or Tin Diamonds," by a gentleman who went annually to Cornwall, but the promise proved to be illusory. In consequence of the great value of tin-stone, it is very carefully searched for by the Cornish miners, who always expect to discover tin wherever granite and clay slate are found in each other's company. The veins of copper and tin usually run due east and west, whilst those containing lead (as already mentioned), are generally at right angles to them. When the tin-stone has been carried away by the decomposition, in ages past, of the outcrop of the tin lode, through the agency of water and the continued action of atmospheric causes, it is of course transported to the valleys and lower levels, and when picked up is called a "shode stone." With a kind of superior Red Indian sagacity, the miners sometimes succeed in tracing the stone to its source; hence the old Cornish proverb, "He knows tin." In ancient times they were firm believers in the use of the "divining rod," made of hazel, and cut in the winter. Agricola gives us an amusing illustration of the use of this supposed indicator of the whereabouts of mineral wealth; and not only are persons

seen cutting and using the willow "dowsing rod," but others are sinking shode pits in order to find surer evidence of the presence of tin or copper. The insecurity of the times is marked by the sword in an old scabbard, resting against the tree with the wallet and cloak.

Fig. 175. The ancient Use of the Divining or Dowsing Rod. A. Virgula, or little rod. B. Fossa, a trench. "Virgula divina" is a Latin idiom, meaning, "When things succeed without our care, and fall as it were into our laps from heaven."—CICERO.

Sir Walter Scott, in his pleasing novel of "The Antiquary," introduces the subject of the divining-rod in the following passage: "In truth, the German was now got to a little copse-thicket at some distance from the ruins, where he affected busily to search for such a wand as should suit the purpose of his mystery; and after cutting and examining and rejecting several, he at length provided himself with a small twig of hazel terminating in a *forked end*, which he pronounced to possess the virtue proper for the experiment that he was about to exhibit. Holding the forked ends of the wand each between a finger and a thumb, and thus keeping the rod upright, he proceeded to pace the ruined aisles and cloisters, followed by the rest of the company in admiring procession. 'I believe dere was no waters here,' said the adept, when he had made the round of several of the buildings, without perceiving any of those

indications which he pretended to expect. 'I believe those Scotch monksh did find de water too cool for de climate, and alwaysh drank de goot comfortable Rhine wine; but aha! see them.' Accordingly, the assistants observed the rod to turn in his fingers, although he pretended to hold it very tight. 'Dere is water here about, sure enough,' and turning this way and that way, as the agitation of the divining-rod seemed to increase or diminish, he at length advanced into the midst of a vacant and roofless enclosure, which had been the kitchen of the priory, when the rod twisted itself so as to point almost straight downwards. 'Here is de place,' said the adept, 'and if ye do not find de water dere, I will give you all leave to call me an impudent knave.'"

The tin lodes are nearly perpendicular, seldom varying more than twenty degrees, and are sometimes worked to the great depth of 1800 feet. The "tin floors" occur at much lesser depths, and represent nearly horizontal strata, containing the tin-stone. Near the Botallack Mine, in the parish of St. Just, in Penrith, Mr. Henwood states, are the remains of very ancient works called "tin floors." The mineral appears to have been disposed in irregular kidney-shaped masses or bunches.

When the tin ore is obtained from the mine, it is called "spaller," and is arranged like copper ores, in heaps of different qualities, according to the external appearance; it is then "dressed," or deprived of the earthy matters by modern machinery, which is a vast improvement upon the old methods. As the analysis of a mineral in the laboratory is usually commenced by pulverizing the substance, so in operations on the grand scale, the question of "fine division," or pulverization, is one of great importance, and there are several degrees of fineness obtained either by

1. Crushing mills.
2. Stamping mills.
3. Edge or horizontal mills.

These different mechanical methods of reducing the ore to powder are like the degrees of comparison; the latter, No. 3, reducing the stony matter to the most impalpable powder, whilst the ancient stamping mill appears to take the intermediate position, and has already been depicted at p. 244.

Tin ores are usually subjected to the stamping mill, of which the best and most complete examples are to be found in Cornwall. Some idea of the work performed by these huge pestles may be formed when it is stated that at "Great Hewas" three tons of pulverized tin-stone per single head or stamp, pass through grates having seventy holes per square inch every twenty-four hours. A small stream of water, as shown in the next cut (Fig. 176), carries the particles through the holes when they are reduced sufficiently fine, or else a motion would have to be given to the box in which the stamps work, in order to shake the pulverized ore through the holes in the iron grates. The stamped ore passes into receptacles or cisterns, fifteen feet long, ten inches deep, and eighteen inches wide, having a gradual inclination of about three quarters of an inch in a foot, and so arranged that whilst one is being

emptied the other may be filling; and the mechanically-suspended mineral matter carried off by the water is not allowed to escape until it

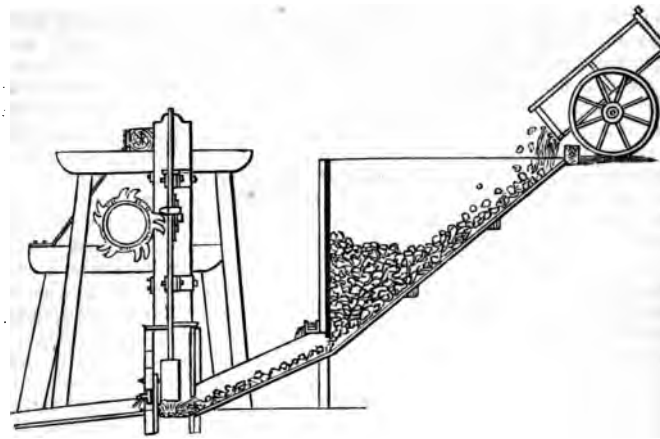


Fig. 176. Modern Stamping Mill. (Henderson.)

has deposited in some degree the precious freight in pits called "slime pits." The cisterns already alluded to being inclined, will of course present the usual results obtained by slowly moving a series of particles of different specific gravity with a stream of water. The top or part of the cistern nearest the stampers will retain the best and heaviest tin-stone, and the lowest division the more earthy particles or "tailings," whilst the intermediate portions will make up the series of three qualities into which the powdered ore is divided.

The head-first or best ore is carried to a square cistern or buddle, also slightly inclined, and by the skilful adjustment of streams of flowing water is again divided into two parts, which take, as before, the same relative position, viz., the best ore at the head and the worst at the tail of the buddle or square trough.

The head ore is then passed through the "tossing tub," which is nothing more than a strong iron-hooped tub, into which ore and water are placed, then stirred up with a shovel, allowed to settle, and the subsidence hastened by striking the sides of the vat with a hammer. When the water is drained off the powdered mineral is found disposed in layers, of which the best is this time at the bottom and the lightest or least valuable at the top. Constant every-day practice enables the workman to take out each layer separate from the other, either to undergo subsequent washing processes or to be placed on one side for the smelting process. The "packing kieve" is likewise worked by machinery, the

hammers being forced outwards by a notched wheel, and brought back again with a spring against the sides of the vat. Mr. James Henderson, in his valuable paper "On the Methods adopted in Cornwall in dressing Tin and Copper Ores," read before the Institute of Civil Engineers, thus describes the processes of "tossing" and "packing." A large circular tub, about three feet eight inches in diameter, termed a kieve, is nearly half filled with water. Two boys or girls then taking the "work" to be tossed in their shovels, place it gently down the side of the kieve (Fig. 177) into the water, which is constantly stirred with a shovel by a third boy, until the water rises (from the addition of the tin stuff) to within two inches of the top of the kieve. The "tosser" always stirs the ore in one direction, thus giving it a circular motion. As the object of "puddling" was to separate the rough, poor matrix from the tin, so that of "tossing" is to get out the fine matrix. The "kieve" being now full, the operation of "packing" at once begins, and merely consists in a boy or a girl striking repeated blows on the edge of the kieve with an iron bar, one end of which rests on the ground. About a quarter of an hour is usually occupied in "packing," although sometimes an hour may be requisite, according to the nature of the stuff,

Fig. 177. Tossing and packing Tin Ores. (Henderson.)

the fine tin stuff taking a longer time to "pack" than that of rougher quality. The vibration imparted by the process of packing to the contents of the kieve causes the subsidence of the tin stuff, according to its specific gravity, with greater regularity than it would have done had it been at once left at rest after tossing. Directly the process of packing is completed (which is ascertained by feeling the degree of hardness of the subsided tin stuff with a shovel hilt), the water is baled out into a second kieve placed alongside when "tossing;" and some fresh tin stuff is again carried on. When the author visited the tin works in the neighbourhood of Tavistock he was much surprised to learn the value of certain heaps of "dressed tin-stone," which an ignorant person might very well have passed by as comparatively worthless.

The circular "buddle" is used for washing and separating the rich ore contained in that portion of the tin-stone left in the central part of the cistern connected with the stamps. The buddle is worked by machinery, and therefore this description of poorer stamped ore is washed and subdivided at a cheaper rate than by the hand labour used with the richest tin ore. The circular buddle is a very ingenious piece of machinery, and deserves notice here, being not only employed in washing tin, but also copper and lead ores.

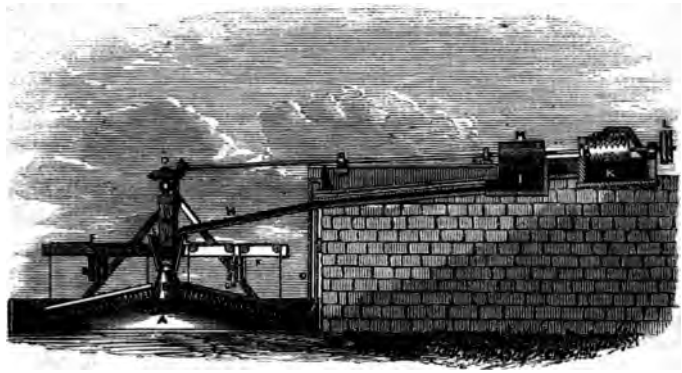


Fig. 178. The Round Buddle. A is a conical floor, formed of wood, about eighteen feet in diameter, on which the stuff is distributed. B is a cone effecting the regular distribution of the orey matter, and supporting the upper part of the apparatus. C is a cap piece forming the centre of motion. D. A water wheel for giving motion to the buddle. E. A funnel perforated with holes, and furnished with an annular trough on the top. F F are arms for carrying two brushes, which may be balanced by weights G G, as shown, or raised by a small arbor placed on the top of the beam; H is a launder for conveying slimes from pit I. K is a receptacle in which the orey slime, mixed with water, is worked up by the tormentor, which is a cylinder of wood carrying a number of iron knives. L is a pulley taking motion from a water-wheel or other prime mover. M is a circular sieve fixed on the arbor N. The slimes at K are gradually worked over a bridge forming the side of a catch pit between the sieve M and the tormentor, from whence the stuff passes into the sieve, and by its rotation the finer particles are strained into the pit I, whilst the coarser are discharged with chips and other extraneous matter upon the inclined floor communicating with the launder O. From the pit I the slime flows by the launder H into the funnel E E, and after passing through the perforated holes, trickles down the sides of the fixed cone B, when it commences to flow off towards the circumference, leaving by degrees, in its downward progress, the heavier constituents, whilst the surface is constantly swept smooth by the brushes, which revolve together with the funnel and vertical shaft, so that the particles of different densities will be arranged in concentric circles.

The "slimes," or matter washed away by the water, are dressed by "the trunking process" and racking table (a modified racking buddle very like that described and used in the time of Agricola, and depicted at p. 246), and worked by a hand-frame (Fig. 179). It is thus by stamps, and a complicated series of washing processes that a certain portion of the small per-centage of tin-stone in the associated matrix is mechanically

separated from the earthy matter, but this is accomplished with a considerable waste of the actual particles of the tin-stone.

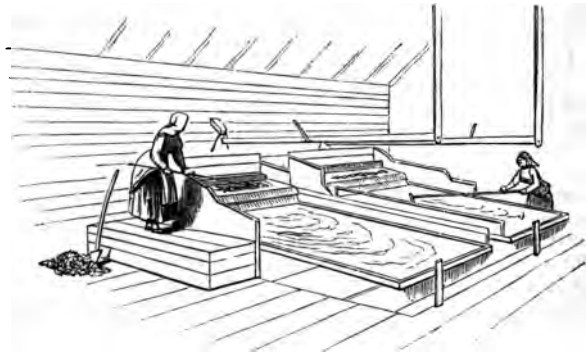


Fig. 179. Hand Frame. (Henderson.)

Common tin is reduced from mine tin, whilst "grain tin," which is the purest metal, is made from tin obtained from the alluvial deposits or "stream works." Mr. W. J. Henwood gives a very interesting description of the strata at the "Carnon Stream Works," a few miles from Truro. The enumeration of the strata is peculiarly instructive, showing that the tin must have been washed away from distant sources, and then covered up in process of time with other earthy and sandy matters: the following is the order of the deposits:—

	ft.	in.
Sand and mud	3	0
Silt and shells	0	10
Sand and shells	2	0
Silt	12	0
Sand and shells	3	0
Silt and shells	12	0
Silt and stones	18	0
Vegetable matter, wood and leaves	1	6
The tin ground	12	0
Total depth down to the clay slate rock	64	4

In this excavation were found a number of the antlers of the deer, the horns of the elk, and the horns of the ox—some of gigantic size and in fine preservation; these lay in the diluvial strata of earth, stones, and trees. A rare discovery was made of a human skeleton, which was not supposed to be coeval with the deluge that caused the formation of the *seam;* the individual probably perished in the attempt to procure some

of the much-prized mineral; there was a peculiarity about the skull, as it partook of the Negro form in a marked degree, and was radically different from the European or Asiatic. Near this spot was found a shovel or spade, formed of a knotty part of the heart of oak; from the appearance of the point it bore evidence of its having been long used. The handle had disappeared, but had evidently been fitted into a hole formed in the spade, and tied there by a thong, which was perfect, owing its preservation, probably, to the tanning qualities of the oak. A pick also was found, formed of one of the prongs or forks of a stag's antler; that had also been tied to the handle, but the tie and the handle were not discovered. The whole of these primitive implements of mining before described, together with the skull, bones, and horns, are now in the possession of the Royal Cornwall Geological Society, and grace their Museum at Penzance. Human bones and skeletons have been met with, and occasionally more or less mineralized, in old deserted galleries in mines. Some years ago human skeletons were discovered in a compact calcareous rock in the Island of Guadaloupe, and sent by Admiral Cochrane to Lord Melville, who placed them in the British Museum; the rock, on examination, proving to be a mere alluvial mass

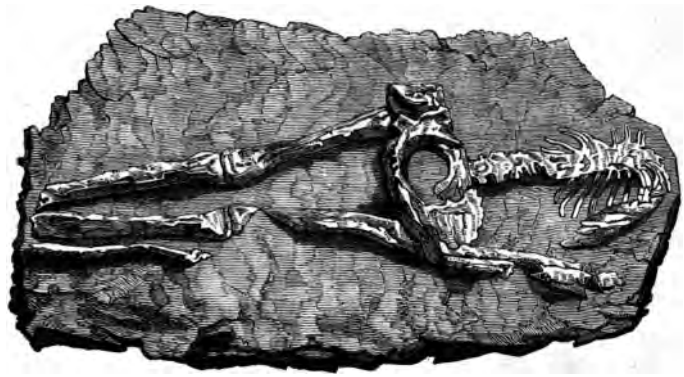


Fig. 180. Human Remains embedded in an Alluvial Mass.

formed of pieces of coral, that appear to have been thrown up on the shore by the sea, and afterwards united together by water containing carbonate of lime in solution.

The great Carnon Stream Tin Works commence near the Carn Brea Hill, or mountain, in the parish and near the town of Camborne, and after a circuitous route of about nine or ten miles through the parishes of Illogan, Redruth, Guennap, Stythians, and Perran, terminates between the parishes of Feock and Mylor at Restronguet Creek, a branch of Falmouth Harbour. It has a gradual fall the whole distance, being, in

fact, the bed of a large rivulet, from which the Stream Work derives its name. Mr. Henwood considers that these deposits of tin ore, &c., are the strippings of the granite ranges, still in existence, such as Carn Brea; and he further remarks, "It has long been held that the veins of tin in Cornwall have not been disturbed by the great deluge which formed the beds of tin found in the streams, the backs of the lodes presenting no indication of such an event; that is to say, no veins have been discovered bearing evidence of having been cut off, as it were, at the surface, leaving the course of ore bare, which must have been the case had this occurred. Again, the tin found in the veins is of a different appearance and quality to that found in stream works, the latter being generally purer and richer, and altogether of another nature. Are they not the *débris* of ancient hills, the ruins and wreck of mountains? . . . . My own opinion, from close attention to the subject, is, they are the strippings of the granite ranges still in existence, such as the 'Carn Brea,' and other mountains of a similar character, whose tops and heights are now denuded of the argillaceous and micaceous slates (both tin and iron-bearing strata) that once covered them."

The above remarks are peculiarly interesting because it is always most satisfactory to trace results to their causes; and in geological investigations the sources of alluvial matter will always be a question of great moment.

The reduction of tin from its mineralized state appears to have been

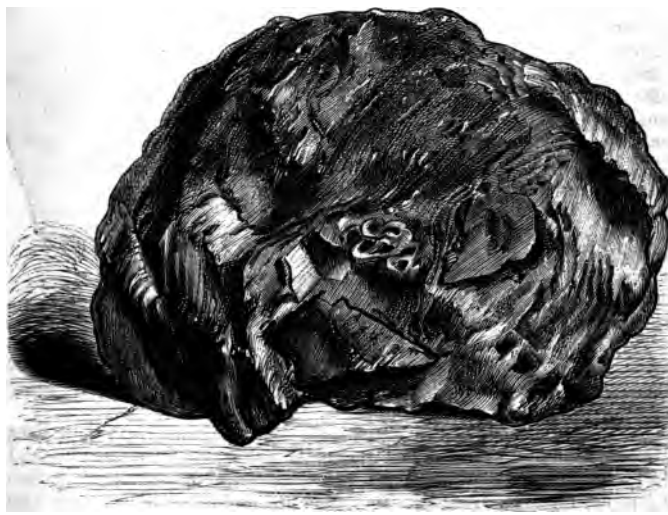


Fig. 181. Ancient Ingot of Tin marked with an Oriental Cypher, called Jew's Tin, because the tin mines were farmed by the Jews in the reign of King John.

carried on in Britain by the Phœnicians, or some persons connected with them; as small blocks and ingots of well-refined tin have been found in Cornwall, marked with cyphers that have been cast in the metal, and not stamped or cut after fusion. (Fig. 181.)

The weapons used in the Trojan war must have contained tin, and "Homer" informs us that it entered into the composition of the armour of Agamemnon, and the shield of Achilles, being called by the immortal poet, κασσίτερος. The second King of Rome, Numa Pompilius, one of the wisest monarchs that ever reigned, appears to have formed a craft, or brotherhood, of the artificers in brass, who, no doubt, sometimes employed tin. If the ancients succeeded in smelting and refining tin, the moderns have certainly not been backward in appreciating the importance of this metal, and Richard Earl of Cornwall, the brother of King Henry III., appears to have made certain special laws for the tin works and tinners, which were confirmed in a charter by his son Edward on the payment of a certain tribute, or rent, upon the tin obtained. King Edward III. confirmed and increased the former charter, and created the first Lord Warden of the Stanniers of Stannum (tin).

The tin ores of Devon and Cornwall are all smelted, according to the ancient laws, within the counties where they are mined. Dr. Ure very properly remarks that private interest suffers no injury from this prohibition, because the vessels which bring the fuel from Wales for smelting these ores, return to Swansea and Neath laden with copper ores.

The process of smelting tin ores is much more simple than that of copper ores, and consists in roasting and calcining the powdered and "dressed" tin ore, either with or without charcoal, in a proper reverberatory furnace to expel the sulphur and arsenic; and then, after washing the roasted ore, it is mixed with small coal or culm, and a little lime or fluor spar, as a flux, and reduced at a higher temperature to the metallic state, and the tin is cast into blocks. This process is called "smelting." The blocks of tin are again melted, and subjected to the action of billets of wood thrust into the liquid metal. The decomposition and escape of steam and gas from the wood causes the melted tin to enter into a state of violent ebullition, by which a sort of scum rises to the top, and is skimmed off. The metal is now allowed to settle, and it spontaneously arranges itself in three strata. The top is the purest tin, the middle is the second quality, the bottom the very impure metal. This process is called "refining."

The arsenic driven off in the roasting process is carefully collected in condensing flues, and after being again sublimed, is sold in commerce under the name of white arsenic, or white arsenious acid ($As O_3$). Frequently the tin ores are associated with the mineral called "wolfram," which is a double tungstate of iron and manganese; and as the two minerals are very nearly of the same specific gravity, it is evident that the mechanical processes of stamping, and washing by the cistern, buddle, trunk, tossing tub, and racking table, will not separate the ore of tin from the wolfram. The aid of chemistry has therefore been invoked, and Mr. Oxland, of Plymouth, has devised a most ingenious

and successful process by which the ores of certain tin mines (that fetched a lower price than others in consequence of the presence of wolfram) have been deprived of this impurity, and now command the highest market price. Tungstate of soda, used by dyers as a mordant, is produced in this process; and lately the author was informed by Mr. Oxland that it was likely the metal tungsten would be in demand in consequence of the remarkable hardness and toughness it imparts to iron when alloyed with that metal. Tungstate of soda is now recognised as an anti-combustible salt, and is applied to muslin and other light goods in the preparation of non-inflammable fabrics for ladies' garments. It has long been known that a material of cotton or thread could be in great measure preserved from the effects of flame by soaking in a solution of alum or common salt. The expedient is a simple one; but in practice is liable to objections which, more than any wilful disregard or carelessness, have prevented its general employment. The fabric that is soaked in common salt becomes crisp and harsh to the touch, while that which is saturated with alum is seriously injured by the process, losing its strength by reason of the action of the salt upon the fibre. The chemist was therefore called upon to discover a substitute which would exert no injurious effect upon the colour, the appearance, or the strength of the material to be rendered non-inflammable. The investigation—one of considerable research and some difficulty—was undertaken by Messrs. Versmann and Oppenheim, to whom the thanks of the ladies are due for a long series of experiments made in their behalf. It was found that borax exerted a powerful preservative effect; but that the combination of the chemical ingredient impaired in some degree the strength of the material operated upon. The effect of more than forty different salts was then tested in the laboratory, the Royal Laundry, and various muslin manufactories; and a reagent was at length discovered answering in every respect the requirements of the manufacturer, who, it is to be observed, finishes his muslin without the application of a hot iron. But more was yet required of the chemist. The amount of the reagent in question—viz., the phosphate of ammonia required for a perfect preservative effect—was very considerable; and, moreover, the salt decomposes under the iron of the laundress, rendering the operation of ironing after its employment a matter of some difficulty. The sulphate of ammonia—a salt only one-fourth the price of the phosphate—was found advantageously to replace the latter for the purposes of the manufacturer, a similar preservative action being obtained with a much smaller amount of the reagent. Both salts, however, are soluble in water, requiring renewal after washing; and both are liable to the same objection with regard to the ironing process. A substance was therefore required to answer a domestic purpose, and which, while allowing the hot iron to pass smoothly over the surface of the prepared material, would afford a perfect guarantee against the effects of flame, without injuring in any degree the strength or appearance of the fabric. A salt fulfilling these conditions was ultimately discovered by the above-mentioned chemists in the tungstate of soda. This salt is now in con-

stant use in her Majesty's laundry at Richmond; and it is to be hoped that its application may quickly become general. It remains only for the wearers of light summer fabrics to require that their goods shall have undergone the preparation through which their wearers will be preserved from the dangers resulting from accidental ignition, and that the laundress also shall employ the tungstate solution of the domestic difficulty in obtaining the same desirable result of safety against fire.—*Mechanics' Magazine.*

Tin, symbolized by the name of the planet Jupiter, in consequence probably of its brilliancy, and now known by the symbol Sn, approaches very nearly in its external appearance to silver, having a silvery, but yellowish-white aspect, which, after slightly tarnishing, remains of a permanent and dulled white colour. Its specific gravity is 7·285, stated by some to be 7·9, and this observed difference in the density of the specimens of tin arises probably from the presence of other metals, such as lead, arsenic, copper, iron, &c., which, with some others, are frequently met with in commercial tin. In consequence of its softness, tin is deficient in elasticity, though, if cast and laminated between rollers, and consequently hardened, it is found to possess more elasticity than is usually attributed to it.

The malleability of tin is made available in the manufacture of tinfoil, which is about $\frac{1}{1000}$th of an inch thick, and used so extensively in the silvering of mirrors. The tenacity of tin is placed very low down in the scale of perfection, although it is curious to notice how difficult it is to break one of the long and almost fibrous, but crystallized fragments of tin; and probably if the mechanical structure of a bar of tin could be assimilated to the condition of bars of fagotted iron in which the fibres are all one way—viz., in the direction of the length—it would be found that tin has a considerable amount of tenacity. In wire made of ordinary tin, the crossing of the crystals would naturally suggest points of weakness, and this may account for its very low tenacity. When a bar of tin is bent backwards and forwards, it emits a peculiar crackling sound, in consequence of the friction of the crystals upon each other; when heated a little below its melting point, 442° Fah., tin becomes brittle, and its fragments exhibit a granular or fibrous structure. If melted tin is poured into a wooden box and quickly shaken, it is reduced to a powdery state, and becomes finely granulated.

Tin is employed in the manufacture of tin-foil, and especially in the coating of iron plates, called "tin plate." These iron plates are prepared by immersion in weak sulphuric and hydrochloric acid, and being well rubbed with sand and washed with water, are deprived of all oxide or rust; they are then passed into a bath containing melted tallow, and from that into one of melted tin, which alloys with, and remains on, the surface of the iron. The plates are subsequently brought to a smooth and bright surface by other dippings in baths of tin and tallow. Bergman discovered that tin and iron form two definite alloys; the one consisting of two of iron and one of tin, and the other two of tin and one of iron. Tin plate has that peculiar crystalline appearance conferred

on its surface, called "moirée métallique," by the action of dilute "aqua regia" or nitrohydrochloric acid. If the tin plate is previously heated in various parts by the flame of a spirit-lamp, each spot where the flame has been applied becomes the centre of a most beautiful series of crystals, which are brought out on the application of the diluted aqua regia.

Before the acid is applied, the "tin plate" reflects the light with tolerable uniformity; but after being rubbed with the acid the facets or faces of the crystals of the tin all present minute but different angles, and the light is unequally reflected.

Bell metal, speculum metal, bronze, Britannia metal, plumbers' solder, pewter, queen's metal, &c., are all alloys which contain tin. Amalgams of tin and mercury are used for lining glass globes, or still better, an amalgam of two parts of mercury, one of tin, one of lead, and one of bismuth. Tin and mercury are sometimes mixed together, and used by quacks for stopping decayed teeth, but the intelligence of the present age no longer permits educated dentists to use a mercurial amalgam which may in time produce the most distressing results by actually salivating the unfortunate person in whose tooth the mercury has been placed. If teeth are stopped with metal, it should be with *pure* gold leaf, which lasts as long as the walls of the hollow tooth remain intact. Boilers for dyers are frequently made of tin, also worms for rectifiers' stills, and many other utensils.

Mr. James Webster, Birmingham, has patented some metallic alloys containing tin:—No. 1, for reflectors, is composed of nickel three parts, copper six parts, tin twelve parts, and antimony one part. No. 2, which may be used for most purposes where white alloys are usually employed, is composed of two parts of alloy No. 1, twenty parts of tin, and a quarter part of antimony. No. 3, for bearings of shafts and like purposes, is composed of twenty parts of copper, twenty parts of zinc, and twenty parts of alloy No. 1.

The forgers of ancient times employed tin in excess for the purpose of imitating the silver currency. The cruel reign of Nero appears to be specially represented by base coin containing a large excess of tin.

Experiments with Tin.

First Series.

The following method of making the assay of a tin ore is recommended by Messrs. Abel and Bloxam, whose valuable work, entitled "The Hand-book of Chemistry," should be in the possession of all those who wish to acquire a more complete knowledge of chemistry, and also of the best and most convenient methods of analyzing minerals and other products:—

"The powdered tin ore is heated to redness in order to expel any water; it is then weighed in a small porcelain boat, and introduced into a tube of porcelain or hard glass through which a stream of dry

hydrogen is passed. The tube is heated to dull redness by a gas burner or a charcoal fire, when the binoxide of tin is easily reduced. The reduced residue is allowed to cool in the atmosphere of hydrogen, and the tin dissolved in hydrochloric acid, with the aid of a few drops of nitric acid. The weight of the tin may then be either directly ascertained by determining it in the solution, or by calculation from the amount of silica left undissolved, which is collected for that purpose on a filter, washed, dried, ignited, weighed; the latter method is obviously applicable only when no other metal but tin is present in the ore."

Second Series.

The combining proportion of tin is 59, and it unites with oxygen in various proportions, forming definite compounds, the chief of which are

Protoxide of tin.	SnO
Binoxide of tin, or stannic acid .	SnO_2
Metastannic acid	Sn_5O_{10}

Protoxide of tin is prepared by precipitating a solution of chloride of tin, SnCl, by carbonate of ammonia, and then boiling the precipitate hydrated oxide of tin, SnO,HO. By this process it is obtained in crystalline plates of an olive colour, which, if heated in a porcelain crucible, take fire suddenly and burn like tinder, producing the binoxide of tin.

Tin stone is the natural mineral form of the binoxide of tin, SnO_2, obtained by heating the oxide of tin in air or oxygen, or decomposing the bichloride of tin with water. This oxide of tin unites with alkalies, forming stannates, of which the stannate of soda is prepared in considerable quantities as a mordant in dyeing and calico-printing. It is this oxide which is used in conjunction with glass to form a white enamel.

Metastannic acid is prepared by slowly heating the hydrated stannic acid; and also by the action of nitric acid on tin, which attacks the metal when it is sufficiently diluted, with great rapidity. After the action of the nitric acid is over, no tin is found in solution, because the metastannic acid is insoluble in water and acid. If some slaked lime is now stirred in to neutralize the remaining nitric acid, the vapour of ammonia is immediately rendered evident, when an excess of lime has been added, and is evolved in such quantity that it can be distinctly perceived by the nose, and of course affects the turmeric test-paper very strongly. To account for the production of ammonia it is only necessary to remember that the water is partly decomposed, and its hydrogen in the nascent state passes to the nitrogen of the nitric acid, with which it unites and forms ammonia; this alkali is masked by the excess of nitric acid, and does not appear until displaced by the lime.

Stannate of the oxide of tin, SnO,SnO_2, is another curious example of the manner in which the same metallic element may perform the part of acid and base by uniting with different proportions of oxygen gas.

Third Series.

Chlorine, iodine, brumine, and fluorine all combine with tin. The chlorides of tin are the most important, and are manufactured and used in large quantities by dyers. The two combinations of chlorine and tin are

The chloride of tin . . . $SnCl$
The bichloride of tin . . . $SnCl_2$

The chloride of tin, $SnCl$, is usually prepared for commercial purposes as the hydrated chloride, $SnCl_2Aq$, by digesting hydrochloric acid on pure granulated tin, with the assistance of a moderate heat; the saturated solution is poured off to crystallize, and the mother liquid evaporated gently, as long as it affords crystals, which are sold under the name of "salt of tin." Such is the violence with which dry chlorine will attack tin, that if passed through a narrow pewter pipe connected with a receiver, a larger quantity of the vapours of the bichloride are produced, and the heat generated is so great that the pewter pipe generally melts down.

The bichloride, $SnCl_2$, is made by distilling carefully six parts of tin previously amalgamated with one part of mercury, and mixed with thirty parts of bichloride of mercury. The distillation must be made in a capacious retort luted to a receiver, and may be conducted over a charcoal fire, the heat of which should be equalized by surrounding the lower part of the retort with coarse wire gauze. The bichloride distils

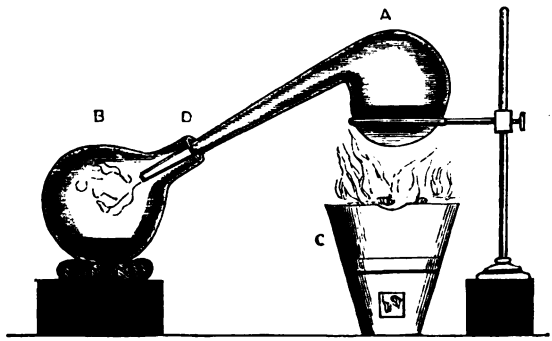


Fig. 182. A. The retort, having the lower part protected by a cap of rough wire gauze. B. The receiver. C. The charcoal fire. D. The lute, composed of linseed meal and a little water.

over and condenses in the form of a colourless fluid, known to the old alchemists by the name of the "fuming liquor of Lebarius," because it evolves white suffocating fumes when exposed to the air, which contains *invisible* steam or aqueous vapour, that unites with it and forms visible

hydrated bichloride of tin. This curious liquid is rather more than 2¼ times heavier than water, and its vapour is nine times heavier than air; it has a great affinity for water, and produces a hissing sound (similar to that of anhydrous phosphoric or sulphuric acids), when dropped into water. Like the strongest nitric acid, it has the power of inflaming turpentine when suddenly poured upon it.

Fourth Series.

Both the chlorides of tin are used in dyeing, and it is by precipitating a solution of chloride of gold with a mixture of these chlorides of tin that the finest "purple of Cassius" is obtained.

The solution of the chloride of tin is called by dyers *plum spirits*, because it is employed in the preparation of the mixture of the decoction of logwood and chloride of tin called the *plum tub*. It is used in calico-printing, both as a mordant and a deoxidizing agent, and the solution of protoxide of tin obtained by adding potash or soda to the precipitated oxide until redissolved, is frequently employed instead of the proto-chloride.

The deoxidizing power of a solution of chloride of tin is shown directly it is added to one of the sesquioxide of iron, when the latter is converted into the protoxide. If a solution of chloride of tin is poured into one of corrosive sublimate or the bichloride of mercury, it is first reduced to the state of chloride of mercury, or calomel, and this latter is further deoxidized and converted into a grey precipitate of minute particles or globules of metallic mercury, which gradually coalesce and form more visible indications of the presence of quicksilver. An excess of the tin salt is absolutely necessary to produce these results.

When exposed to the air, the solution or the crystals of chloride of tin absorb oxygen, and binoxide and bichloride of tin are produced; but this is usually prevented in practice by the addition of a little chloride of ammonium, which forms a double salt, less disposed to change than the single one. The colours obtained by uniting stannic acid, SnO_2, with the colouring matter, are much brighter than those procured with the protoxide of tin, probably on account of the gradual change it undergoes at the expense of the oxygen of the colouring principle. Although the protoxide is employed in the first place because of its ready solubility, and the facility with which it enters the pores of cotton fabrics; it may be subsequently converted into the higher oxidized state of stannic acid by rinsing the cloth containing the protoxide in a weak solution of chloride of lime, which is an oxidizing agent. Stannic acid is used as a mordant in the form of the perchloride prepared in a peculiar manner by dissolving tin very slowly, without heat, in weak nitric acid containing a little chloride of ammonium; this solution is called *red spirits*. "Pink salt," chiefly used as a mordant with peach wood, is prepared by adding chloride of ammonium to perchloride of tin, and evaporating to obtain crystals.

The peroxide of tin is employed in fixing the colouring matters obtained from logwood, peachwood, barwood, Brazil-wood, cochineal,

&c. The use of this mordant is well shown by dipping a skein of German white wool (previously well wetted and rinsed in clear water and squeezed out) into a hot infusion of cochineal; on removing the skein and washing away the excess of colouring matter, it is found to be very faintly coloured; but if another skein is previously dipped into a weak solution of "red spirits," or if a little red spirits are poured into the hot cochineal whilst the skein is immersed, and the whole well shaken together by moving the skein in and out of the dye bath, it will be found to be dyed of a beautiful red or crimson colour, and if rinsed in water to remove the excess of dye, the colour of the wool is no longer faint, and is quite fixed.

The important application of the salts of tin in dyeing with cochineal was discovered by a German chemist of the name of Kuster, who lived at that locality of concentrated chemical and putrescent odours called Bow, about the year 1550. His discovery was the means of bringing cochineal into much larger consumption. Beckman states that the first-mentioned use of "kermes," or cochineal, in dyeing seems to have been continued through every century. In the Middle Ages, as they are called, we meet with "kermes" under the name of *vermiculus*, or *vermiculum*; and, on that account, cloth dyed with them was called *vermiculate*. Hence the French word *vermeil*, and its derivative vermilion, which latter originally signified the red dye of kermes, but is now used for the sulphide of mercury or cinnabar.

The chloride of tin is used as "a resist" or means of preventing the discharge of colour. Thus, if a piece of indigo-blue dyed cotton or linen cloth is spotted over with a solution of chloride of tin, and then dipped into one of chloride of lime or bleaching-powder, the latter attacks and bleaches all parts of the cloth not protected by the tin salt, which combines with the excess of chlorine, and then undergoing further change, is converted into stannic acid.

Fifth Series.

The reactions obtained when the protochloride of tin is added to the various solutions of other metals may all be termed effects of deoxidation, and the following table, taken from Dr. Normandy's excellent dictionary to his "Chemical Atlas," affords some notion of the variety of experiments that may be performed with this reagent. It is of course understood that the solution of chloride of tin is quite pure, and Fresenius recommends the following method of preparing it:—

"Fuse a certain amount of English tin in an iron spoon, and after having removed the latter from the fire, triturate the fused mass with a pestle until it has completely solidified. Introduce the powder which is thus obtained into a flask, pour concentrated hydrochloric acid over it (always taking care that the tin predominates), and boil the mixture; dilute the solution subsequently with four times its bulk of water slightly acidified with HCl, and filter. Pour the filtrate into a phial containing small fragments of metallic tin, and close it carefully."

SOLUTIONS OF	COLOUR.	REACTIONS.
Oxide of silver	*White*	Precipitate, if the quantity of the solution of protochloride of tin is small; a larger quantity produces a
	Brown	Precipitate of metallic silver.
Protoxide of platinum ...	*Brownish red*	Colour.
Peroxide of platinum	*Dark reddish brown* ...	Colour.
Protoxide of palladium ...	*Black*.....	Precipitate (Pd); the superincumbent liquor has a beautiful *dark green colour*.
Peroxide of rhodium	.....	Gives to the red solution a
	Dark brown	Colour, but *no precipitate*.
Deutoxide of iridium	*Light brown*	Precipitate.
Deutoxide of osmium.....	*Brownish*	Precipitate.
Peroxide of gold	*Purple*	Colour and in more concentrated solutions
	Deep purple or brown ...	Precipitate (purple of Cassius) $(Au_2OSnO_2),(SnO,SnO_2)4HO$.
Sulphurous acid	*Brown colour*	And afterwards
	Brown or yellowish	Precipitate.
Protoxide of mercury.....	*Grey*	Precipitate whilst boiling reduced to globules of mercury.
Peroxide of mercury	.....	A small quantity of reagent forms a
	White.....	Precipitate Hg_2Cl; but if an excess be added,
	Grey	Precipitate—metallic mercury.
Tetrathionic acid	*White*.....	Precipitate.
Hyposulphurous acid.....	*Brown*	Precipitate after a time.
Osmic acid	*Brown*	Precipitate; soluble in HCl, and the solution is then brown.
Tellurous acid	*Black*.....	Precipitate of metallic tellurium.

Sixth Series.

Sulphur combines with tin, and forms the sulphide of tin SnS, and the bisulphide SnS_2. The latter, under the name of "*aurum Musivum*," "mosaic gold," or "bronze-powder," is prepared by first making an amalgam of twelve parts tin with six parts mercury, which is then powdered and mixed with six parts of chloride of ammonium and seven parts of flowers of sulphur; this mixture is then placed in a mortar or glass flask with a long neck, arranged in a thin iron pot surrounded with sand over a proper furnace. A gentle heat is applied until the white fumes cease to appear, when the temperature is raised to redness, and kept so for some time. On cooling, the *aurum Musivum* may be obtained by breaking the matrass. It is of a beautiful gold colour, and in flaky, six-sided scales, which are very pretty. The fumes which arise during the operation should be allowed to escape up the chimney, as they contain mercury, and may produce dangerous results *if* inhaled; or the whole process could be conducted over a common fire, by using an iron ladle as the sand-bath for the Florence flask or matrass. Bronze-powder is used for touching the edges of painted plaster busts, also by house-painters and paper-stainers.

Seventh Series.

The tests for tin are classified under two heads—viz., those which produce a reaction with solution of the protoxide of tin, and those which affect the binoxide of the metal.

Sulphuretted hydrogen gas precipitates a dark-brown sulphuret of tin (SnS) from neutral and acid solutions of the protoxide, but not from alkaline solutions. The precipitated sulphuret is soluble in potash and sulphide of potassium, also in strong boiling hydrochloric acid.

Caustic soda or potash precipitates a white bulky hydrated protoxide of tin (SnO,HO), soluble in an excess of the alkali.

The carbonates of the alkalies, potash, soda, and ammonia, produce the same result, but do not re-dissolve the precipitate.

Perchloride of gold added to a solution of the protoxide of tin with a little nitric acid produces the characteristic precipitation of "purple of Cassius."

Bichloride of mercury is reduced first to the state of calomel (white), and then to minute metallic globules, grey in the presence of an excess of the protoxide of tin.

Bichloride of platinum produces a blood-red colour in solutions of the protoxide of tin, which very much resembles that obtained by the addition of sulphocyanide of potassium to a persalt of iron; when diluted with water, no precipitate occurs, and yet, strange to say, if the bichloride of platinum is added to a very *dilute* solution of the chloride of tin, a reddish-brown precipitate is obtained.

Eighth Series.

The binoxide of tin (SnO_2) and persalts of tin being already saturated with oxygen, do not reduce the other persalts of the metals to the metallic state. The white powder—metastannic acid ($Sn_5O_{10}10HO$) produced, when tin is acted upon by nitric acid, is insoluble in nitric and dilute sulphuric acids, but concentrated sulphuric, hydrochloric, and tartaric acids dissolve it.

The precipitate (SnO_2HO) obtained by decomposing bichloride of tin (*the fuming liquor of Libavius*) with water is white and soluble in alkalies and acids; but when strongly heated, it is converted into the insoluble form, like the white powder obtained when tin is acted on by concentrated nitric acid; but the insoluble form is converted into the soluble by fusion with carbonate of soda.

It has been shown that, in the preparation of certain solutions of tin for mordants, the bichloride of tin may be obtained in the soluble form; if sulphuretted hydrogen is passed through a solution of a persalt of tin, the metal is precipitated as the hydrated bisulphide (SnS_2HO), which is a light yellow precipitate.

The solution of the persalt of tin may be acid or neutral, but if alkaline, sulphuretted hydrogen does not precipitate the bisulphide; hence the latter is soluble in the alkaline sulphides and in pure alkalies and their carbonates. Concentrated and boiling hydrochloric acid slowly dissolves the bisulphide of tin.

Hydrosulphuret of ammonia produces the yellow precipitate of bisulphide of tin, soluble in an excess of the precipitant. Metallic zinc

precipitates tin from solutions of the protochloride or perchloride of tin which are free from excess of nitric acid. Metallic tin so obtained is a grey, spongy mass, which, if washed and dried, frequently takes fire spontaneously on the application of a very moderate heat, and is converted into the oxide of tin. If the solution of tin contains an excess of nitric acid, the precipitate no longer consists of metallic tin only, but is a mixture of stannic acid with that metal.

Fig. 183. Botallack Tin Mine at St. Just, near the Land's End, Cornwall, and worked under the sea for a distance of more than half a mile.

Fig. 184. The Dutch Alchemist working with Salt, Sulphur, and Mercury. The unprofitable nature of alchemy is shown by the empty money-bag and the grief of the wife.

CHAPTER IX.

MERCURY. ☿

The ancient sign represents the wand, or caduceus, of the god Mercury.

If there was one substance more than another which agitated the philosophic minds of the earliest alchemists, it certainly was this metal,

which suggested the most delusive hopes of its capability of conversion into solid silver. Geber, the Arabian prince already alluded to most respectfully in the chapter on Alchemy, seems to have been convinced that it was nothing but silver united with moisture, and if he could only succeed in driving it off, that a solid would be the result. The chroniclers of his chemical experiments inform us that he succeeded in changing mercury to a solid, but only with the vexatious result of the entire loss of all the beautiful characteristics of the metal—its brilliancy, volatility, &c., were all entombed in the new form which it assumed, of a red powder or calx. Geber does not appear to have understood the nature and composition of the calx or earth, and it was not till August, 1774, that Priestley discovered the nature of Geber's earth, and proved it to be a compound of oxygen and mercury.

That the idea of changing mercury by driving off its supposed moisture, was prevalent long after the time of Geber, is shown by the patient experiments of Boerhaave, who is stated to have distilled mercury twelve hundred times, obtaining, as everybody knows, in these learned times, only one result—viz., the matter, the mercury, he originally started with. What a sensation such a story as this headed, "Mercury in the Bones of a Corpse," related in a French journal, would have produced amongst the old alchemists; and how many corpses would have been ruthlessly torn from their last resting-places if they had only conceived that the principle of transmutation began with the corruption and decay of our mortal remains, out of which, Phœnix-like, the transmuting essence was to arise.

"A wealthy farmer, having died, was buried in the tomb where his father had been interred thirty-five years before—viz., at the burying-ground of Whittington, near Shrewsbury. A veterinary surgeon, who presided at the ceremony, took the necessary precautions to prevent the bones of the father from being broken by the pickaxe of the grave-digger. On examining the place where they lay, he was surprised to perceive in the bones of the sternum brilliant particles of a metallic lustre, and in other parts of the thorax he found a similar appearance. All these particles being collected together, presented a considerable quantity of oxide of mercury, which it was easy to reduce to the metallic state. Thus for thirty-five years the mercury had been preserved, almost without alteration, in the body of the deceased, who had probably been in the frequent use of the metal during the latter part of his life." Geoffroy, at the request of an alchemist, placed a quantity of mercury in an iron globe strongly bound with iron hoops, and then placed the shell into a furnace. Directly it became red-hot the globe burst with great violence, and the mercury was dissipated in vapour.

The metals, and especially quicksilver, were favourite objects of study with the ancients, and, as Dr. Percy remarks, "*metallurgy may indeed be said to have given birth to chemistry.*"

The use of quicksilver is traced by learned authors to the ancients, who were acquainted, according to Pliny, with the process of amalgamation for the separation of gold and silver from their associated earthy

matters, and likewise for gilding. Vitruvius details minutely the manner in which the gold thread was obtained from cloth, with which it was interwoven; the ashes of the cloth, after burning, were collected in an earthen vessel and mixed with water and quicksilver, which latter takes up and amalgamates with the gold. The fluid amalgam is then squeezed through a cloth, and the gold remains in a compressed mass, and this is precisely the method of amalgamation adopted by the Australian gold diggers. "I was invited," says the author of "Life in Victoria," "into their dwelling tent, which was as trim and tidy as a woman's hands could make it (for Mr. N. had another treasure besides his reef); and while his hospitable wife was preparing luncheon, he amused himself by exciting my amazement to its uttermost bounds, as he pulled cake after cake of solid amalgamated gold, like so many Dutch cheeses, from under his bed, until I absolutely thought either that I was labouring under an optical illusion, or that he was producing a clever trick, like that of pulling a market-cartful of cabbages out of a single hat. However, it was neither the one nor the other, but a palpable reality, a marvellous fact of the most stubborn description."

Beckman, in his "History of Inventions," remarks: "That it is in the thirteenth century he finds the first undoubted mention of glass mirrors covered at the back with tin or lead;" and some time between that and the sixteenth century, the art of silvering mirrors, as at present conducted, with the aid of tinfoil and mercury, appears to have been in common use.

Mercury is found in nature in the metallic and mineralized states, and is said to be discovered in rocks that belong to the same period as those which are associated with the coal formations. The ores are usually accompanied with iron pyrites, heavy spar, calcareous spar, quartz, and sometimes copper ore; indeed, the usual constituents of what we have already termed nature's gigantic electro-deposit cells, veins, or lodes, are likewise to be found in connexion with them. The following are the chief ores of mercury:—

Name.	Constituents.
1. Native mercury	Mercury.
2. Native amalgam; fluid or semi-fluid, and solid . .	Mercury and silver.
3. Mercurial horn ore, or corneous mercury	Mercury, chlorine, oxygen, sulphur.
4. Mercurial liver ore, or hepatic ore	Mercury, sulphur, carbon, silica, aluminum, oxygen, iron, copper, water.
5. Red cinnabar or sulphide of mercury	Mercury, sulphur, with occasionally bituminous matter, gangue, and water.

Pliny states that the Greeks imported red cinnabar from Almaden, in Spain, 700 years before the Christian era, and that Rome received 700,000lb. weight annually from the same source. The most important

mines which yield quicksilver are at Almaden, Peru, Idria in Austria, and in the Palatinate on the Rhine.

At Almaden and Idria the cinnabar, after being pulverized and sometimes washed, was formerly placed with some lime in earthenware vessels, termed cucurbites, which were attached to a long succession of earthen tubes, called aludels, and already depicted at p. 121. The cucurbites or retorts were gradually heated for many days in succession, and during this time the lime united with the sulphur of the cinnabar, and the mercury, being volatilized by the heat, condensed as it passed through the aludels and fell into the proper receivers. The late Dr. Ure, however, suggested and carried out a great improvement in the distillation of mercurial ores, and by using common iron gas retorts and collecting the mercurial fumes with greater care, he was enabled to prevent waste and economize the cost of the whole process.

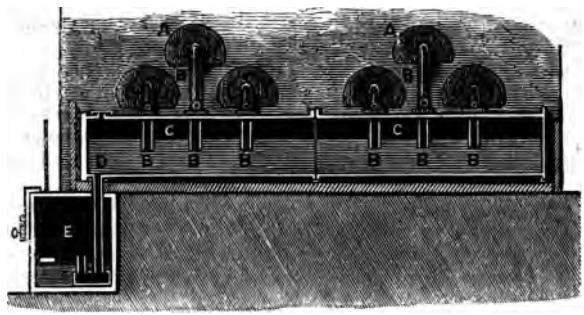


Fig. 185. A, A. The retorts. The pipes leading from the retorts marked B. C C. The condenser of cast iron nearly filled with water into which the pipes B dip. D. Pipe through which the condensed mercury falls into the iron chest E, which is provided with a float and rod to indicate the quantity of condensed mercury.

Although potassium is soft like wax at ordinary temperatures, and is liquefied at the low temperature of 136° Fah., there is no other metal but mercury which remains fluid at common temperatures. The specific gravity of mercury is very high, and amounts to 13·595; the brilliancy of this metal is remarkable, and its colour is white and very slightly tinged with blue. The boiling point of mercury is stated to be about 660° Fah.; and considering the high temperature required to change the opaque metal to the condition of a transparent vapour, nearly seven times heavier than air, it is somewhat curious that it should volatilize not only at ordinary, but even below the common temperatures of our climate.

Mercury placed in a stoppered bottle, with a bit of gold leaf suspended above it, volatilizes slowly, according to the experiments of Faraday, at a temperature varying between 60° and 80° Fah.; but in the winter months no trace of vapour (by the test of the whitening of the gold leaf) could be detected. Karsten, however, states that the

volatilization of mercury is perceptible even at the freezing point of water; and the experiment of the latter coincides with the generally-received notion that all bodies that assume the state of vapour may slowly volatilize into the atmosphere, which is supposed to contain a little of everything capable of being vaporized. It is right to state Faraday has proved that this is not true in all cases, and he has ascertained, by a series of experiments conducted during four years, that many chemical bodies which vaporize at 300° and 400° Fah., do not evaporate when kept in a confined space with water.

Mercury solidifies at a temperature of 40° below zero on Fahrenheit's scale, and, like water, expands at the moment of freezing; this fact is proved by the *decrease* in its specific gravity, which is 13·39 in the solid state, instead of 13·595. If mercury continued to contract in bulk whilst freezing, the specific gravity would be higher than that of the liquid state.

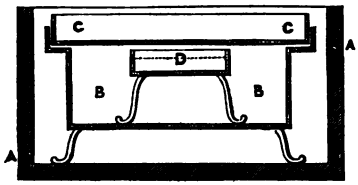


Fig. 186. Apparatus for freezing Mercury.

Henry describes a very simple and cheap contrivance for freezing quicksilver by chloride of calcium and snow. The outer vessel of wood may be twelve and a half inches square and seven inches deep. It should have a wooden cover, rabbeted in, and furnished with a handle. Within this is placed a tinned iron vessel, B B, standing on feet which are one and a half inch high, and having a projection at the top half an inch broad and one inch deep, on which rests a shallow tin pan, C C. Within the second vessel is a third, D, made of untinned sheet iron, without any solder at the corners, and supported by feet two inches high. This vessel is four inches square, and is intended to contain the mercury. When the apparatus is used, a mixture of chloride of calcium and snow is put into the outer vessel A A, so as completely to surround the middle vessel, B B. Into the latter, the vessel, D, containing the quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow and chloride of calcium, previously cooled to *zero* Fah. by an artificial mixture of snow and common salt. The pan, C C, is also filled with these materials, and the wooden cover is then put into its place. The vessels are now left till the quicksilver is frozen. A more elegant, but more expensive apparatus is that employed for the solidification of carbonic acid by Robert Addams; when mercury is placed in a dish with ether and solid carbonic acid, the intense cold produced by the sudden liquefaction and evaporation of the ether and carbonic-acid gas, solidifies the mercury, which assumes very much the property of lead and tin so far as malleability and tenacity are concerned. By means of solid carbonic acid and ether Mr. Addams succeeded in freezing ten pounds of mercury in less than eight minutes: the same gentleman placed a lump of solid carbonic acid in a red-hot crucible for one minute, and afterwards froze a

pound of quicksilver with it. For use in the Polar regions the thermometers are filled with absolute alcohol instead of quicksilver, which solidifies and bursts the bulbs under the influence of the intense cold of those inhospitable and dreary portions of our globe. In the late Sir John Franklin's second journey to the shores of the Polar sea, in 1825–26–27, a Mr. Kendall froze some mercury at the temperature of — 52·2° Fah. in the mould of a pistol-bullet, and fired it against a door at the distance of six paces. A small portion of the mercury penetrated to the depth of one-eighth of an inch, but the remainder only just lodged in the wood. Mercury is not only employed for filling thermometers, as described in the "Boy's Playbook of Science," p. 360, but is likewise used in the construction of barometers or weather-glasses, which are of such immense value to captains of vessels, and also to fishermen, whose lives frequently depend on a foreknowledge of the state of the weather. To meet this want Messrs. Negretti and Zambra, of Hatton-garden, have constructed a very cheap instrument, which they call the "Fisherman's barometer." The scale of the instrument has been devised by Rear-Admiral R. Fitzroy, the head of the Meteorological department of the Board of Trade.

Fig. 187. Negretti and Zambra's Fisherman's Barometer.

The instrument that Messrs. Negretti and Zambra had to devise was a barometer that would bear exposure on a wall, or any other convenient public place, where it could be consulted by all both day and night; and also an instrument that might be carried about from one station to another without fear of the air getting into the vacuum at the top of the barometer tube, and called the Torricellian vacuum. The new barometer is made as follows: The frame, which is constructed of oak, is screwed together with brass screws, so as to render it as durable as possible; if iron screws had been used, they would be liable to rapid corrosion by the action of the salt spray more or less pervading the shores of a sea-port town. The scale, instead of being made of metal or ivory, as heretofore, is made of hard-baked porcelain, the divisions and figures being indelibly marked by a patent process belonging to Messrs. Negretti and Zambra, which is neither more or less than etching and blacking in, and burning in at a low temperature, so as not to run the risk of altering the scale; by this process absolute durability is insured as far as the divisions and scales are concerned; and the whiteness of the porcelain is also a great assistance to the dimmed eyes of some of those who will consult the instrument. The glass tube is four-tenths of an inch diameter internal measurement; thus securing a column of mercury which is perfectly distinct and visible. The tubes, with their mercury, are *all boiled* — an operation very rarely performed except in few cases, and then only by one or two makers, because the operation is attended with considerable risk both pecuniary and personal, for as many as seven or eight large tubes out of a dozen will break in boiling. The operation consists in filling a tube with mercury and then holding it over a pan of charcoal until the mer-

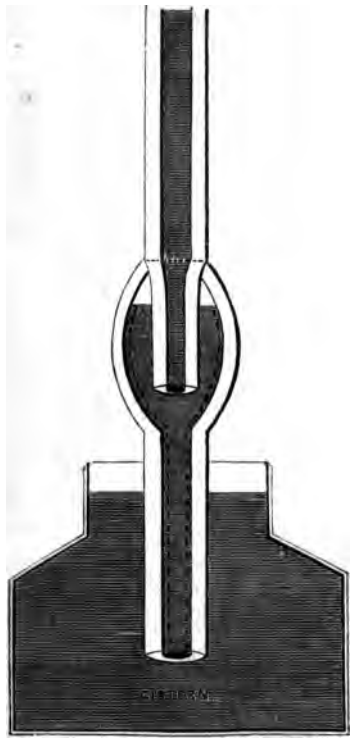


Fig. 188. Negretti and Zambra's ingenious arrangement to prevent the air creeping up the inside of the barometer tube.

cury boils inside the tube; by this process all the air is expelled. With respect to the mode of stopping the gradual creeping of the air up the inside of the barometer, for enter it will, in spite of bags, platina rings, and all such contrivances, a most ingenious contrivance is employed, which may be termed a *trap*. (Fig. 188.) This consists of a stout bulb of glass welded an inch or so over the open end of the barometer tube; and, by reference to the preceding woodcut, it will be seen that, as the air only creeps up between the glass and the mercury, it is stopped in the top space of the glass bulb or trap, whilst the end of the barometer tube, being immersed in the mercury, is cut off from communication with the sides of the tube dipping into the cistern of mercury. If the air was permitted to remain in the trap, it might certainly creep into the main tube at last; but then it must be remembered that, on the first occasion the barometer is turned upside down, which can be done with perfect safety, all the air goes out of the trap, and the barometer is as perfect as the first day it was made. It may be urged that, if the quantity of air that creeps into the tube is so small, there need not be such a fuss made about trapping it; but it must be remembered that the one-thousandth of an inch of air let in at the bottom of the barometer tube becomes expanded to one inch when it arrives at the top, or Torricellian space, and hence the absolute necessity of excluding the smallest bubble of air in a good barometer.

Mercury is employed in the extraction of silver from its ores, likewise in the manufacture of looking-glasses, and also in certain processes of gilding. The science of medicine has long been indebted to mercury for some of its most powerful remedies, which produce, when taken in excess, very frightful effects on the human system. One of the prettiest applications of mercury is that lately made by Professor Way, who employs it for the electrodes of his new electric lamp instead of the solid poles usually made of carbon. (Fig. 189.) The mercury is contained in an upper cistern connected with one wire of the battery, and allowed to flow through a capillary aperture into a closed glass tube communicating with a lower cistern also connected with the other wire of the battery. At the moment of contact between the globules of quicksilver falling from the upper cistern to that retained in the glass forming the upper part of the lower one, the metal is ignited, and produces a constant though flickering light, which may be continued for any length of time, so long as the upper cistern and the battery are kept supplied with their respective quicksilver and acids.

"Some exceedingly interesting experiments took place off Osborne House, the beautiful marine residence of her Majesty, in the Isle of Wight, and also in Cowes-roads, with Professor Way's electric light, and which we believe are preliminary to more important experiments about to be carried out by the Government. The principle of the light is simply the application of electricity to a column or running stream of quicksilver—in this instance as fine as the point of a lady's needle. So long as the voltaic battery retains power to act with its wires upon this column, so long must the light burn—the strongest and purest

light in the known world, and the nearest approach to sunlight that the skill of the chemist and man of science has yet produced, and this without actual combustion taking place or the quantity of the mercury being reduced, the supply of acids to the battery being its sole expense after its first cost, excepting wear and tear. The Professor with his apparatus left Portsmouth harbour in a steamer shortly before dark, and steered direct for Cowes. On the sponson of the steamer was placed the battery. Abaft the foremast hung one of the Professor's simple apparatuses as a masthead light. On a moveable circular platform placed on the vessel's after-hatch a similar apparatus to the one hung up aloft stood, to which was attached a lens, but both of them as yet unlit. The apparatus is one of the simplest possible form, consisting merely of an oval-shaped pair of tubes connected at each end, with a round hollow globe about the size of an orange, in which is placed the mercury. The mercury runs from a point to a cup in the centre, enclosed within a glass tube, and here the subtle liquid is heated to a white heat as it flows in a fine stream from the upper ball into the cup, and thence into the lower one, thus producing an indestructible wick. The wires which connect the battery with the apparatus were made by Messrs. Silver, and are, perhaps, the most perfect of their kind yet constructed. These wires are coated with silver, enclosed in india-rubber, and have an outside coating of braided hemp, the whole pliable as common packthread. To look at the light, with a view to a close inspection of the cup, with the naked eye, would be about as useless as to look at the sun at noonday. A pair of coloured glasses, however, show that this light, which can only be compared to the sun for its brilliancy and power, is only of the same circumference as the cup itself—the size of a threepenny silver piece, and of little more diameter. Midway between the aftermost light and the voltaic battery is a brass standard a few inches high, with which the wires are connected, and by pressing a button on the top of this, simple as the key of a piano, the light can be given in flashes of as long or as short a duration as the operator pleases. This is, however, more beautifully and correctly carried out by a small instrument of Mr. Way's. It consists of a piece of clockwork, having in front a revolving disc, the face of which is covered with numerous holes with pins to fit in as may be required. In front of the disc are two small cylinders with pistons and arms attached. As the disc revolves, the pins in its face lift the pistons in the cylinders and cut off the connexion between the battery and the lighting apparatus, producing flashes of light of any duration that may be required, with their accompanying intervals of darkness, and admirably adapted for a revolving light, or as a code of signals for night service. In fact, there would appear to be no limit to the uses to which this discovery may be applied, and so simple is it in its manipulation that the choicest music of the great masters may be henceforth accompanied by expressive flashes of electric light. When the steamer arrived off the Mother-bank the light aloft was lit by attaching to it the ends of the wires from the voltaic battery. So soon as the glass tube became sufficiently

heated to throw off the mercury from its surface, the light exhibited its power and beauty, the steamer's masthead light, which was hoisted in its usual position, appearing but a dull red speck alongside it. Its effect upon the human countenance was, however, by no means favourable, casting on all on board the steamer a strange unearthly hue. Mauve colour, as it has become fashionable to term it, on the ladies' dresses or bonnets, was brought out by the light with astonishing brilliancy. On reaching Cowes-roads, crowded with yachts, and all displaying lights, the contrast between the electric light and those shown by the yachts was something wonderful. The electric light was shining in its pale pure brilliancy aloft, while the hundreds of lights displayed by the yachts and by the town of Cowes, its clubhouse and hotels, dwindled down to dull red specks. The lens applied to the after light threw broad pathways of light to and fro as the lens might be directed, bathing the low black hulls of the craft that were in the line of light with a flood of sunshine, as also the delicate tracery of their spars and rigging. A boat which left the steamer here for one of the yachts was lighted on its way by the lens. On the steamer's return, Norris Castle was passed, and the light thrown on its picturesque front. Ivy-covered towers, walls, and parapets were illuminated as with a stroke from an enchanter's wand. Off Osborne House the steamer was stopped for some time, and the light must have shown itself with good effect on the still waters of the Solent, in front of the beautiful marine residence of her Majesty. The experiments, which, as already stated, are only preliminary to more important ones, were

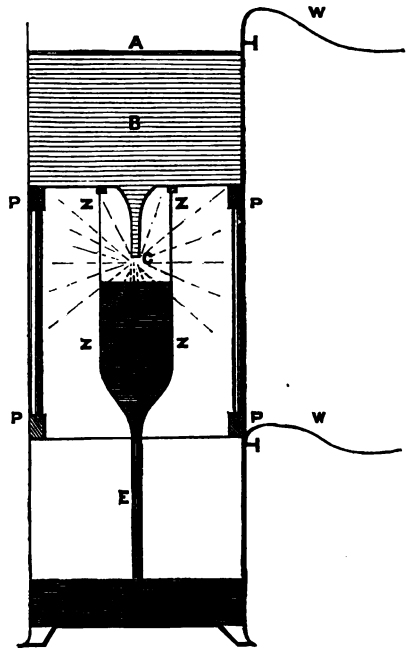


Fig. 189. Way's Mercurial Electric Lamp. A. Upper iron cistern containing B, the mercury, which falls slowly, in a fine stream, through the minute aperture, C, on to a little cup not shown, because invisible when the light is produced, and placed in the glass tube Z Z Z Z, connected with the lower iron cistern, E. The two metallic cisterns are cut off from conducting communication with each other by the non-conducting material inserted at the pillars P P, P P. W, W. Wires passing to the voltaic battery.

considered to have been fully satisfactory. With a light on this principle under her bows, the *Great Eastern* herself might have lighted her path across the waters of the Atlantic."—*The Times.*

Experiments with Mercury.

First Series.

An assay of mercurial ore, such as cinnabar, is easily made by mixing together a weighed portion of the powdered mineral with about five per cent. of dry carbonate of soda and ten of caustic lime, both of which must also be well powdered and mixed with the ore. The whole is then put into a combustion tube after a little bicarbonate of soda has been placed in the closed end of the tube, so that at the last stage of the process carbonic-acid gas may be disengaged, and acting like a broom, sweep off any minute portion of mercurial vapour that might remain and condense in the tube. The mercury is received into a proper vessel, and its weight compared with the loss of weight in the tube will give the per-centage of mercury. The cinnabar must of course be well dried, and any moisture it contains estimated in the usual manner by drying a weighed quantity in an oven heated a little above 212°.

Mercury is easily purified from zinc, lead, copper, &c., by placing it in pans containing some dilute nitric acid; and if the latter is kept at a temperature of about 130° Fah., and the whole frequently stirred, the metal is gradually purified. The proportions are one part ordinary nitric acid and two of water.

Second Series.

The combining proportion of mercury is 100, and it unites with oxygen in two proportions.

The suboxide of mercury	Hg_2O
The oxide of mercury	HgO

The suboxide was first described by that indefatigable chemist Boerhaave, who prepared it mechanically by attaching a bottle containing quicksilver to one of the spokes of a mill-wheel. Homberg, in 1669, had previously made it in the same kind of manner, but Boerhaave was the first to call the black powder so obtained "Ethiops per se," which appears to be insoluble in water, and has a peculiar coppery taste. This oxide is also prepared by triturating calomel with a large excess of solution of potash. It is only interesting to the scientific chemist because it forms the first of the limited series of oxygen compounds of mercury; but the oxide of mercury presents perhaps the most peculiar features of interest, not only because it is probably one of the first chemical compounds ever made by the hand of man, but also on account of its being the substance by which the original experimentalist, Priestley, discovered oxygen. When mercury is boiled for some days in a matrass or flask with a long neck open to the air, so that the volatilized quicksilver is in a great measure condensed in the

upper part of the tube, and falls back again into the body of the matrass, the mercury is gradually converted into the oxide (HgO), which assumes the appearance of red scales, and was called by the alchemists "precipitatum per se." It is a very curious fact that, whilst a certain amount of heat—about 600°—facilitates the combination of the mercury and oxygen, a further increase, amounting to about 900°, decomposes it again into its elements, mercury and oxygen. The usual method of preparing the oxide is by very carefully heating or calcining minute crystals of nitrate of mercury, which gives up its acid, and yields the oxide of mercury in beautiful red scales, called "red precipitate," or nitric oxide of mercury. This oxide appears to be "dimorphous," or capable of assuming two forms, having two different colours — viz., yellow or orange, and red, and we shall have occasion to notice that the same property belongs to the iodide of mercury, which in one state is yellow, and in the other red or scarlet, although both have the same chemical composition.

It is worthy of remark that the oxide of mercury is slightly sensitive to the action of light, and is partially blackened by exposure thereto.

Third Series.

Chlorine and iodine unite with mercury, and form highly-important compounds; bromine and fluorine also combine with mercury, but the resulting salts are of little importance at present. The compounds of chlorine and mercury consist of

The subchloride of mercury or calomel	Hg_2Cl
The chloride formerly called bichloride of mercury or corrosive sublimate	HgCl

Calomel is prepared in various ways; it does not seem to have been made by the alchemists, because Crollius, in the seventeenth century, speaks of it as a great secret, and as the alchemists were generally inclined to describe with considerable prolixity what they discovered, it is possible to conceive that this compound was, at all events, unnoticed by them. The commonest and perhaps one of the oldest methods of preparing it, is to rub quicksilver with corrosive sublimate, HgCl, until the running mercury is said to be *killed* or rendered invisible by minute division. This mixture is then placed in an alembic, and being properly heated in a sand-bath, the impure calomel sublimes, and is subsequently purified by washing with cold water or re-subliming. There are other and better modes of preparing calomel, but as this work only pretends to describe the most popular and characteristic qualities of the metals and their compounds, these processes cannot be enlarged upon. Mercury, when heated, takes fire, if plunged into chlorine.

Corrosive sublimate, HgCl, is one of the most ancient chemical compounds, and is described by Geber. It has been known from time immemorial to the Chinese. One of the most simple processes of making it is to dissolve the oxide of mercury (HgO) in hydrochloric acid; the

oxide dissolves rapidly, and the chloride soon crystallizes; the decomposition that takes place is very simple, and consists in the combination of the oxygen of the oxide of mercury with the hydrogen of the hydrochloric acid; the liberated chlorine and mercury unite and form corrosive sublimate. It is this salt of mercury that is used in preserving timber from the dry-rot by the kyanizing process. Goadby has applied the following solution to the preservation of the most delicate insects, and especially butterflies, with complete success. The latter, inclosed in square glass boxes or troughs containing the solution, and mounted with a gold border, form the most beautiful and ornamental brooches.

Goadby's Solution.

Corrosive sublimate	4 *grains*
Bay salt	8 ounces
Alum	4 ounces
Water	2 quarts

Corrosive sublimate forms an insoluble compound with albumen, which is therefore one of the antidotes recommended in cases of poisoning with this very potent and dangerous salt. It is connected with one of the most interesting episodes in the life of the late M. Thénard, who on one occasion, whilst lecturing to his pupils, drank what he imagined to be water; discovering his mistake, he calmly said, "Gentlemen, I am poisoned: fetch me some eggs." He had taken corrosive sublimate. Inflammation of the stomach supervened, and for many days he lay in the most dangerous state; but his house was surrounded by a triple chain of faithful and admiring pupils, who day and night preserved the utmost quiet in the streets adjoining his house in Paris. His enthusiastic reception after recovering from the effects of the poison may be imagined, but cannot be described.

This well-known story seems to indicate that the whites of eggs are not to be relied on as a perfect antidote in cases of poisoning with this salt, and there are other cases where albumen has failed.

"A gentleman staying at a hotel had swallowed some fluid brought to him by mistake. The mistake originated in the carelessness of a servant, who, after using the solution of corrosive sublimate for the purpose of killing certain nameless insects which prevailed in the bedsteads, had carried the bottle in which it was contained to the bar, and placed it on the shelf where the cider was kept."

Albumen administered ten minutes after the accident failed to save his life. Under these circumstances, Dr. Buckler of Baltimore recommended the use of iron-filings, but M. Mialhe has discovered that the hydrated sulphide of iron will effectually prevent the dangerous effects of corrosive sublimate. The antidote is prepared by dissolving sulphate of iron (green vitriol) in at least twenty times its weight of water which has been boiled to deprive it of air, and then adding enough sulphide of sodium to precipitate the iron. The hydrated sulphide of iron is to be

washed with water by decantation, and may be kept by apothecaries for use in closely-stoppered or corked bottles filled up with boiling distilled water. Chemists and druggists would advance their own interests and those of humanity if they kept on a special shelf the antidotes (in good order) for all the common poisons.

Iodine unites with mercury to form the iodide HgI, by rubbing together the equivalent proportions of mercury and iodine. Thus the equivalent of the latter being 127·1, and the former 100, these would be the quantities in grains or ounces to be triturated. A little alcohol must be used to assist the chemical union of the two elements. Iodide of potassium added to a solution of corrosive sublimate throws down first of all a dirty-yellow precipitate, which rapidly changes, by stirring, to a scarlet. If too much of the iodide of potassium is added, the iodide of mercury is re-dissolved, and this experiment forms one of the most amusing tricks, if carried out with the assistance of a hollow stirring-rod (closed at one end by drawing it out to a thin point), which is to be previously filled with a strong solution of iodide of potassium. If this rod is stirred in the glass containing a solution of corrosive sublimate, no effect is produced until the operator, pretending to get irritated, thrusts the rod violently down to the bottom, and breaks off the pointed end, when the iodide flows out and produces the usual colour; and if the open end of the tube is carefully manipulated with by closing it with the first finger, just enough of the solution of the iodide of potassium may be allowed to escape into the corrosive sublimate to produce the scarlet, and then the whole colour may apparently be stirred away again by permitting an excess of the iodide to escape from the end of the rod. These arrangements require careful adjustment beforehand, and some previous trials with the solutions, to ensure success.

Another amusing experiment may be performed with iodide of potassium and corrosive sublimate, combined with the effects obtainable from

Fig. 190.

oxalate of ammonia, chloride of calcium, and sulphide of ammonium. The object is to obtain from five colourless solutions which are to be

poured from one glass to the other, a scarlet colour becoming colourless, then white, and finally black.

Into the first glass a solution of iodide of potassium is placed, sufficiently strong to give a copious precipitate of the scarlet iodide of mercury when poured into the second glass, which contains a solution of corrosive sublimate. The scarlet contents of the second are poured into the third glass, which contains enough iodide of potassium to redissolve the iodide of mercury, and also some oxalate of ammonium, so that the contents of the third glass become colourless. By pouring some of the third into the fourth glass, containing a little solution of chloride of calcium, a copious white precipitate of oxalate of lime is thrown down, and this again is masked and lost sight of in the dense black precipitate of sulphide of mercury, obtained when the solution, still containing mercury, is poured from the fourth to the fifth glass, containing some sulphide of ammonium. The fifth glass should be covered with a glass plate, to prevent the escape of the disagreeable odour of sulphuretted hydrogen.

The iodide of mercury, when rubbed across a sheet of paper, affords a beautiful scarlet colour, called "geranium colour," which would be employed by artists, if they could only depend upon its remaining permanent; this, however, is not the case, because the iodide of mercury is dimorphous and capable of assuming two forms and two colours, yellow and red; for if the scarlet streak on the paper is carefully heated over the flame of a spirit lamp, it gradually changes to a primrose yellow, and when these yellow crystals are subject to any abrasion, such as scratching them with a pin, the change to scarlet gradually occurs, or it is produced instantaneously by merely rubbing or breaking down the yellow crystals, or again restored to the yellow colour by heating the paper.

Mr. Robert Warrington has investigated this curious change of colour and form with his usual ingenious acumen, and he states* that "when a quantity of the precipitated biniodide [iodide] is sublimed, the resulting crystals are very complicated in their structure, consisting of a number of rhombic plates, of varying size, superposed, sometimes overlapping each other, and causing considerable variableness in their thickness, but generally leaving the extreme angle and the two lateral edges clear and well-defined. The annexed sketch (Fig. 191), taken by the camera lucida from the field of view of the microscope, will give a better idea of their character. The length of these crystals was about ·015 of an inch. On cooling, the first change that is observed is usually a scarlet marking, commencing at the extreme angle, and extending gradually inwards, always retaining a perfectly well-defined line in its progress; when this change has reached so far as the line *a b*, Fig. 191, the scarlet line will suddenly shoot along one of the lateral edges, as shown at *c d*, and instantly the whole mass is converted, in a most rapid and confused manner (which the eye in vain endeavours to follow), to the scarlet colour,

* Memoirs of the Chemical Society, vol. i. p. 85.

the crystal being frequently, if detached, twisted and contorted during the transition.

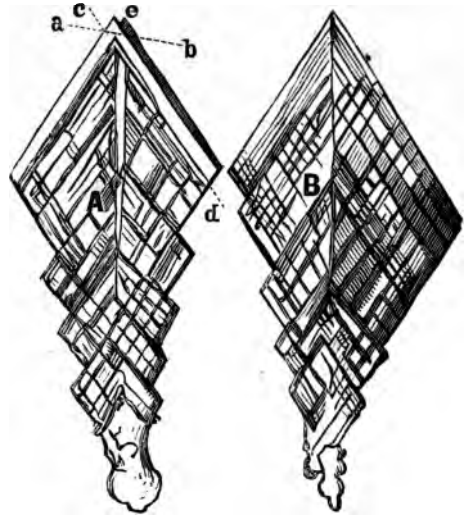


Fig. 191. Crystals of Iodide of Mercury.

"In order to obtain these crystals in a more defined and clearly-developed form, a small glass cell was constructed of two slips of window-glass, leaving a space of about the thickness of cartridge-paper between the upper and under plates, in which the sublimations could be readily conducted, and the whole of the subsequent changes at once submitted to the microscope; by this means, beautifully well-defined and perfect crystals were obtained, having the form of right rhombic prisms, as in the accompanying outlines, Fig. 192, A and B. The following interesting phenomena were then observed; a defined scarlet line of varying breadth would shoot across the crystal as at 1 C, D, E, F, Fig. 192, and then gradually spread throughout the whole of its structure, keeping a straight and well-defined line in its onward progress until the whole had undergone the

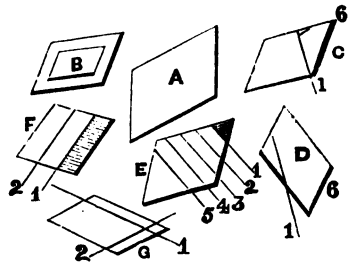


Fig. 192. Iodide of Mercury in Rhombic Prisms.

change of colour. Nos. 2, 3, 4, 5, in E, and No. 2 in F, are the stages which the transition had reached at intervals of observation; in many cases, after the crystal has undergone this metamorphosis, two angles can be distinctly seen as at E, Fig. 191, and at times two edges are visible, as at C 6, and D 6, Fig. 192. This observation must of course depend entirely on the position of the crystal to the eye of the observer. These phenomena prove, I consider, in the most perfect manner, that the change in the colour of this compound arises from the plates of the crystal having been separated from each other by the means alluded to in the direction of their cleavages; and in further confirmation of this view, the laminæ so separated may, by the sudden application of heat, be again fused together, and the yellow colour reproduced without materially altering the dimensions of the crystal, a slight rounding of the edges from partial sublimation being the only other concomitant." These and other careful experiments by Mr. Warrington show that the iodide of mercury has two vapours, which are given off at different temperatures, and also that it is dimorphous, the yellow form being rhombic, and the scarlet octohedral with a square base. Besides the iodide of mercury, there is a sub-iodide (Hg_2I), which is a dirty green colour, and prepared by "triturating an excess of mercury with iodine and a little alcohol." This compound may be fused and sublimed if the operation is performed quickly. There are also the oxychloride, the oxyiodide, and the oxybromide of mercury.

Fourth Series.

The compounds of sulphur and mercury are interesting, because they include the natural compound or mineral called cinnabar, an impure sulphide of mercury, and also the well-known pigment which the Chinese so much delight to use in their gaudy paintings, under the name of vermilion. If some quicksilver and sulphur are shaken together in a tube they quickly unite and form a black compound formerly termed "Ethiops mineral." This experiment offers a good example of the difference between chemical union and mechanical mixture; for if some mercury and lycopodium (which is yellow, and looks very much like sulphur) are shaken together, there is no blackening, but simply a division of the particles of quicksilver, and this is of course a "mechanical mixture." When "Ethiops mineral" is sublimed at a red heat, it forms a fine red colour, termed cinnabar (HgS) or vermilion. The latter name is derived from the French word "*vermeil*," which comes from vermicular, a name given in the mediæval period to kermes or cochineal. The subsulphide of mercury (Hg_2S) is, like many other metallic salts, only interesting on account of its analogies, and because it forms one of a large series of mercurial compounds.

Fifth Series.

The amalgams of mercury are somewhat numerous, and extremely suggestive of chemical solution; indeed, Joule has obtained definite

compounds of mercury with tin, copper, lead, zinc, silver, and platinum. Gold is attacked by mercury, and dissolved in it with considerable rapidity, and the author remembers a case of vanity reproved, in which the mercury contained in a mercurial trough used for certain experiments with gases that are soluble in water, formed the corrective agent. A young gentleman who had made himself conspicuous as a pupil in a chemical class, by wearing a very showy collection of jewellery on his person, was induced by the brilliancy and pretty appearance of the quicksilver in the open trough, to stir it about with his fingers, on one of which was a diamond ring; no one made any remark, a few masonic signs passed between the initiated, but at the end of the discourse a sudden cry was heard, Where's my ring? The *débris* of this precious ornament remained floating and dissolving in its mercurial grave. The diamond alone remained perfect, and this, if the author remembers properly, the other mischievous pupils recommended should be heated red-hot in a crucible with some nitre, and was either burnt away or lost. Chemical pupils or chemists must not wear jewellery in the laboratory, or fear stained fingers. Some of the most curious amalgams of mercury are those made with potassium and sodium, and if some quicksilver is gently warmed and a bit of either of these metals thrust in on the end of a wire, an intense chemical action takes place with the evolution of heat and fire. When enough potassium or sodium, or both, have been added, a solid amalgam is formed, which remains permanent only under naphtha, and is slowly oxidized and changed to potash or soda and running mercury when exposed to the air.

The amalgam for electrical machines is made by melting one part of zinc with one of tin, and then agitating the liquid alloy with two parts of mercury placed in a wooden box; when cold, it must be finely powdered and kept in a well-corked or stoppered bottle for use.

Mercury is used for amalgamating the plates of zinc used in galvanic batteries. The best plan is to boil some solution of washing soda in a saucepan, and first dip the zincs therein for the purpose of removing the grease with which the plates are more or less covered when they first come from the zinc worker. They are then to be placed in a weak solution of corrosive sublimate containing some hydrochloric acid, and are finally coated with mercury by dipping them into a vessel containing that metal, or else by pouring some over both sides of the plate and spreading it well with a stick having a bit of flannel tied on one end with stout silk. Cotton is soon rotted and destroyed. The plates must be allowed to drain in any convenient dish, or else a good deal of quicksilver is wasted.

An amalgam, composed of four parts of mercury and one of bismuth, is sometimes employed to coat the insides of glass globes used for ornamental purposes; and if subsequently protected by a varnish composed of wax dissolved in turpentine, they will remain bright for a considerable period.

For scroll and arabesque work, and imitations of illuminated me-

diæval works, "powdered gold," made by first amalgamating gold with mercury, and then distilling off the latter, is used; the proportions are one of gold to eight of mercury.

Sixth Series.

The salts of the oxide of mercury are mostly white, and of a very disagreeable metallic taste. If nitrate of mercury, HgO,NO_5, is mixed with an excess of water, it is decomposed into basic nitrate, having a yellow colour, which, by continual washing, is converted into the red oxide of mercury.

Solutions of chloride of tin (SnCl) and sulphurous acid (SO_2) precipitate metallic mercury from its solution in very minute globules, which appear grey until they are warmed and coalesce.

The subsalts of mercury are precipitated black by solutions of potash, soda, and ammonia; salts of mercury, which are persalts, like the nitrate of mercury or the chloride of mercury (corrosive sublimate), are precipitated yellow by solutions of potash or soda, and white by ammonia.

The subsalts of mercury are precipitated black both by sulphuretted hydrogen and sulphide of ammonium; if the black precipitate (Hg_2S) is collected, washed, dried, and heated in a test tube, a sublimate is obtained containing little globules of quicksilver.

With the same tests persalts of mercury are also precipitated black, and in the use of sulphuretted hydrogen the precipitate becomes white, then yellow, orange, brownish-red, and black, being truly the embodiment of the living chameleon. If this precipitate is heated in a test tube, the sublimate contains *no* globules of quicksilver, and its composition is H,S.

Iodide of potassium throws down a yellowish-green precipitate with subsalts of mercury; but with persalts a beautiful scarlet precipitate, soluble in an excess of a solution of iodide of potassium or of chloride of mercury.

One of the most delicate tests for mercury is, perhaps, the one pointed out by Smithson. If a little of any oxide or saline compound of mercury be put in a drop of hydrochloric acid on *gold*, together with a little tin, the gold will be amalgamated by the mercury and exhibit a white spot; and as a gold coin is easily obtained, and hydrochloric acid is by no means scarce, the test is readily applied, and will detect very minute quantities of mercury. If the mercury is in a very finely divided but metallic state, it must be placed on the gold with a drop of nitric acid evaporated to dryness, and the hydrochloric acid and tin subsequently applied.

Frampton recommends the use of finely divided silver when the presence of soluble chloride of mercury is suspected. The finely divided silver obtained by electro deposit is boiled with the fluid suspected to contain the mercurial salt, and being allowed to subside, the liquid is poured off. The silver is then boiled with potash to remove organic matter, and washed; it is then heated with ammonia to remove the

chloride of silver, and being finally dried and placed in a glass test tube, is heated and the mercury sublimed, when it forms a metallic ring in which globules of mercury are clearly visible by a magnifying-glass.

Copper gauze or plate may also be employed, like gold, for the detection of mercury, by the white spot of amalgam left on its surface.

Fig. 193. The God Mercury and his Caduceus.

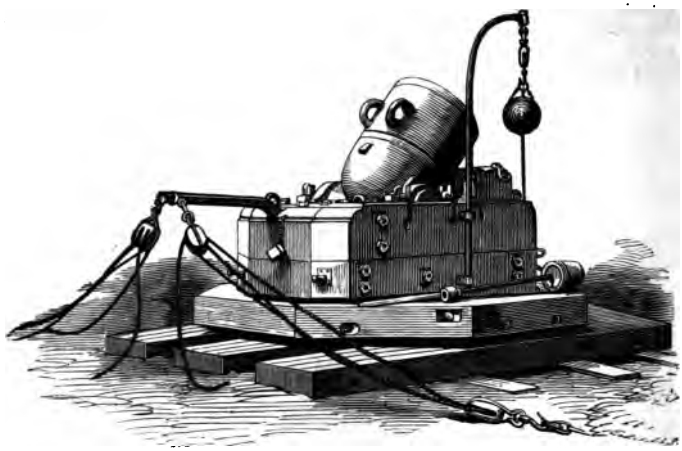


Fig. 194. Thirteen-inch Sea-service Mortar.

CHAPTER X.

IRON. ♂

The sign represents the lance of Mars, the God of War, together with his shield.

It has been well said "that there could be no effectual civilization without iron. From the moment that a people acquires the art of making it malleable, they cease to be savages, and in proportion as they acquire skill in its fabrication, they may be said to be civilized." Fortunately for mankind, therefore, iron is the most abundant, the most widely-diffused, and the cheapest of all metals. It is, at the same time, one of the most difficult to reduce from the ore to the metallic state, and yet, with the exception of the savage tribes of America, of Australia, and of the islands of the Pacific, the art has been in the possession of nearly all the other people of the world for more than 3000 years.

By reference to the four books of the Mosaic law, it is evident that Moses (who was born 1635 years before Christ) was acquainted with iron, and that, consequently, the Egyptians and Phœnicians must have discovered its use and value many years before his time. Solomon truly asks, "Is there anything whereof it may be said, See, this is new?" and then observes, "it hath been already of old time, which was before

us." Moses mentions furnaces for working iron ores, from which it was extracted, and clearly states that swords, knives, axes, and tools for cutting stone were then made of that metal.

Dr. Thompson remarks "How many ages before the birth of Moses iron must have been discovered in these countries, we may perhaps conceive, if we reflect that the knowledge of iron was brought over from Phrygia to Greece by the Dactyli,* who settled in Crete during the reign of Minos I., about 1431 years before Christ; yet, during the Trojan war, which happened 200 years after that period, iron was in such high estimation that Achilles proposed a ball of it as one of his prizes during the games which he celebrated in honour of Patroclus. At that period none of their weapons were formed of iron. Now, if the Greeks in 200 years had made so little progress in an art which they learned from others, how long must it have taken the Egyptians, Phrygians, Chalybes, or whatever nation first discovered the art of working iron, to have made that progress in it which we find they had done in the time of Moses?"

It would appear from the writings of Diodorus, Pliny, and others, that the Romans employed iron in the fabrication of their warlike weapons which chiefly came from Spain. Mr. Aikin states that cutting and surgical instruments made of bronze, and some few of iron, were discovered in the excavations at Pompeii, that most interesting of buried cities, situated about five miles from Mount Vesuvius, and entombed by its eruption A.D. 79. Pompeii remained unnoticed and almost forgotten for 1700 years, when it was accidentally discovered by some peasants who were digging a ditch, and since then, the most interesting remains, showing the civilization and luxury of that period, have been laid bare. Seventeen hundred years are certainly a long period for an experiment on the permanency of bronze and iron implements, and it only shows that exposure to air (which contains oxygen and moisture) is the chief cause of that destruction of the useful properties of the iron, and which we familiarly term "rusting."

The iron discovered naturally, with the exception of those great masses of the metal containing five per cent. of nickel or cobalt, that have come to us from unknown sources, and are called meteoric iron, and a very thin band, or rather foil, of metallic iron, found in America, is all mineralized or united chiefly with oxygen or sulphur.

The ores of iron are almost endless in variety and composition; indeed, iron is the most extensively distributed of all the metals, and it not only exists in the mineral, but also in the organic kingdoms, being a constituent of an immense number of natural minerals, and existing as an essential element in the blood of vertebrate animals. It would be too tedious to enumerate the names of all the iron ores that have been discovered and analysed; and therefore, only the most important, and especially those found and used in Great Britain, will be mentioned.

* Hesiod, as quoted by Pliny, lib. vii. c. 57.

Name.	Constituents.
Native iron	Iron, with occasionally a little lead and copper.
Meteoric iron	Iron, with nickel and cobalt.
Iron pyrites	Iron and sulphur.
Arsenical iron pyrites, or mispickel	Iron, arsenic, and sulphur.
Magnetic iron ore, or loadstone	A mixture of the two oxides of iron, $FeO+Fe_2O_3$.
Specular iron or red hematite, red ochre, and iron glance	Iron and oxygen, Fe_2O_3.
Brown iron ore, or hydrated oxide of iron	Peroxide of iron, water, and silica, $2Fe_2O_3+3HO$.
Umber	Oxides of iron and manganese, water, silica, and alumina.
Carbonate of iron	Protoxide of iron and carbonic acid.
Clay ironstone	Impure carbonate of iron, containing oxide of manganese, lime, magnesia, silica, alumina, peroxide of iron, carbon, and sulphur.

It is the clay ironstone which yields, from its varieties of the argillaceous and blackband ironstone, at least nine-tenths of all the iron made in this country. By a beneficent ordinance of the Creator this is generally associated with coal and limestone, the two essentials—viz., the fuel and the flux—required to liberate the iron from its oxygen and earthy matters. The coal basin of South Wales, which includes an area of about ten thousand square miles, affords the largest quantity of iron. A railway journey past Bilston and Wolverhampton reveals to the astonished eyes of the Londoner the wonderful quantities of iron that must be made in Staffordshire, whilst Shropshire, Yorkshire, Derbyshire, and North Wales, all coal-producing counties, are also eminent for the iron they produce. There are very few rules without exceptions, and so it is with the relationship of coal and iron, and the latter is not found in any important quantities in the coal fields of Northumberland, Durham, Lancashire, Leicestershire, and Somersetshire. One of the most remarkable discoveries of iron ore was made a few years since by some gentlemen who were out shooting in the neighbourhood of Cleveland, in the district of North Yorkshire. One of them happened to strike his foot against a lump of rocky matter, and stooping down to look at his enemy, he quickly perceived, from his knowledge of mineralogy, that this lump of stone was a friend in the shape of iron ore, and that it probably came from a much larger bulk. Returning to the same spot, he subsequently discovered that the whole of the estate, consisting of nearly worthless land (at least for agricultural purposes),

was full of iron ore, and, it is said, that this fortunate discoverer was enabled to buy a lease of the land at a very moderate price, which he relet at an enormous profit. The Cleveland ironstone turned out to be of first-rate quality, and was discovered in beds from twelve to twenty feet thick, and extending for miles, with the greatest facilities for working them. A rough calculation estimated that ten millions of tons of ironstone could be obtained by open quarrying alone. The whole of this important mining district has ready access by railway to the prosperous town of Middlesborough, which contained only a few scattered houses some twenty years ago, and is now a town containing from twenty to twenty-five thousand inhabitants, being just the number which the ancient city of Pompeii is supposed to have sheltered within its luxurious precincts.

The Cleveland ironstone, like the iron ores of Northamptonshire, belongs to the oolitic series, and is very similar in its chemical characteristics to the ores of the Wealden group, which have been worked in ancient times in Hampshire and Sussex until the charcoal obtained from the wood of the New Forest and other forests failed to supply the greedy wants of the iron smelters. Devizes in Wiltshire, Lancashire, some parts of Yorkshire, and the Isle of Wight supply limited quantities of the same kind of ironstone. The Cleveland ore has interspersed through its substance an abundance of fossil shells, and contains about thirty-three per cent. of metallic iron. When the author last inquired respecting the treatment of the ore, he was informed that it could be smelted without being previously roasted, and that the expense of that preliminary operation was therefore saved. The following is a section of the strata at one of the localities near Cleveland, where the ironstone is being worked, viz., at the Loft House Works belonging to the Earl of Zetland, and leased to a mining company:—

	Feet.	Feet.
1. Sandstone beds and inferior oolite		50
2. Shale	10	
3. Hard or cement stone	25	
4. Alum shale	150—185	
5. Jet rocks	20	
6. Hard composite shale, very sandy	30— 50	
7. Main ironstone bands		25
8. Sandy shale and iron dogger	48	
9. Shaly sandstone	10— 53	
10. Alternations of calcareous sandstone and sandy shale, generally one sandstone bed	40	
11. Shaly marlstone, slaty sandstone, gradually partaking of the nature of the lower lias shale	20— 60	
12. Lower lias shale below the level of the sea		150
		578

It is evident, therefore, that the chief portion of the iron discovered in a mineralized state is oxidized, or rusted, and in order to recover it from

that condition some cheap material must be sought for which has a great affinity for oxygen. The substance that answers the condition required is carbon, in the shape of coal; and as the equivalent proportion of carbon is only 6, a comparatively small quantity is required when we consider what would be the consumption of this agent if its equivalent was like that of iodine and amounted to 127·1. But this is only another addition to the thousands of other illustrations of the omnipresence of the forethought of the Deity.

The ordinary clay ironstone has been quarried out like stone from the earliest periods of the history of iron manufacture; but when steam-power came generally into use, and the demand for iron increased, mines were sunk into the earth, and nearly all the conditions described in the mining of coal were adhered to, and especially the mode of working out the ironstone by the "pillar and stall system," already explained with reference to coal mining at p. 87. The roof of the mining gallery is supported by stout props made of fir or larch, which are removed as the ore is exhausted, and the superincumbent mass allowed to fall in. The roof is also sometimes further upheld by portions of the useless rock stacked up like a pillar, and called "stons."

The timbering of shafts has already been alluded to in the preceding chapters on the metals known to the ancients; and the consumption of timber in the mining districts is enormous, practical miners being fully aware that there is no economy in having a *deficiency* of timber in the main ways or places where the miners are actually at work. Larch and oak are found to last the longest in mines. When the timber is required for temporary purposes, such as for props and planks (No. 1, Fig. 195), or is to be abandoned in the mine, Scotch

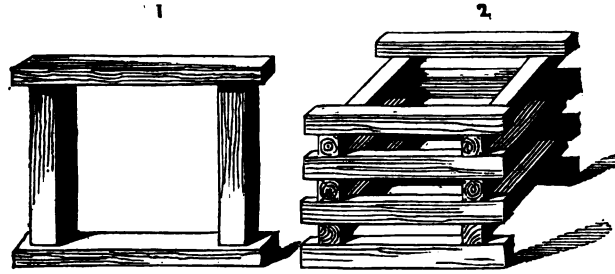


Fig. 195. Timber Supports used in Mines. No. 1. Props and planks. No. 2. A "chock" of timber for supporting the roof of a main way.

fir, alder, birch, and beech wood are to be obtained at a cheaper rate. Sometimes the roof is supported by a number of single props, or, better still, by "chocks" (No. 2, Fig. 195), which are stacks of wood made up of pieces two and a half to three feet long, and equal to four strong props, the

breaking strain being transverse to the fibre of the wood; in fact, the nearer the mining engineer approaches the simplicity of the children's building toys in which the model timbers are all square and not weakened by cutting or morticing, the better for the durability of the work. Such timbering as that depicted in the next cut will of necessity be weakened by cutting away portions of the solid cross pieces at A and B in Fig. 196,

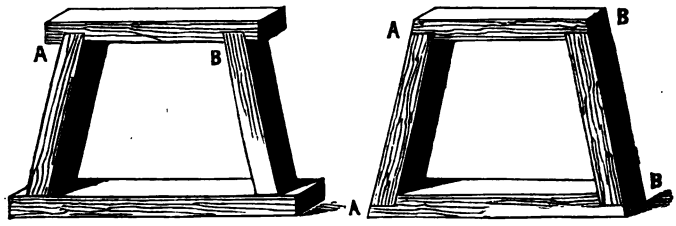


Fig. 196. Timber Supports used in Mines.

and, of course, it is understood that a piece of timber is no stronger than its weakest point; here the whole block is reduced to the strength of the points A, B.

It is in the cost of timbering, through bad ventilation, that the philanthropist gains one of the most telling arguments in persuading the owner to give his miners a sufficiency of air to breathe. When the air in a mine is sluggish, the dampness of the air is increased, and it is charged with different kinds of animal and other odours, which communicate their foul condition to the wood, and produce the growth of a fungus which eats into and destroys the heart of the stoutest timbers; and it has been declared by a thoroughly practical mining engineer that at least eighty per cent. of the timber now wasted in mines could be saved by improving the ventilation. Bad air, fire-damp, and choke-damp are not the only difficulties the miner has to fight against; there is the steady infiltration of water, that would in time convert a mine into a huge cistern well, in which no man could possibly work unless he went down in a diving-dress, which is, of course, too ridiculous to be thought of. Hence the necessity for the erection of powerful steam-engines and complete pumps, by which the water is removed from mines. It was in the first year of the present century, when bread had reached famine prices, that the whole future of George Stephenson was changed by his successful attempt to drain a mine that had baffled all previous attempts. The great engineer had determined to emigrate, but this piece of fortune, or rather wisdom, made him at once a "man of mark," and he soon rose to an eminent position.

Mr. Mark Fryar, one of the eminent lecturers of the Bristol Mining School, gives the following advice to prevent accidents to life and property arising from the inundation of coal or other mines—viz.,

"Accurate surveying and mapping; a due consideration of the lithological character and properties of the rock dividing the surface or underground water from the places of the mine in progress; *carrying narrow exploring drifts in the subterranean districts where water may be expected*, with bore-holes in advance, the length of the holes depending very much on the tenacity and texture of the material being excavated; supporting water with strong and durable dams where it is to be kept to the rise of the working parts of the mine, and by leaving pillars of the material being worked, sufficiently strong to support the roof. When the workings extend under the sea or river, it is of very great importance that the plans of all underground operations be properly kept, and every excavation accurately registered, so that when the mine is worked out and filled up with water, as is the case in a great many instances, the surveyor of a neighbouring mine may, with some degree of confidence and certainty, direct the workings thereof to a certain point in the direction of the drowned mine, and thereby save all the expense and much of the anxiety attendant on a sort of blundering and daring adventure into the regions of the unworked mineral, only known to be there in certain quantities by the hearsay of some two or three generations back. What can be more dangerous than the position of men in the deep workings of a coal mine, when to the rise of them are lying several thousand cubic yards of water, only prevented from rushing upon them with fatal violence by a thin barrier of coal that "bleeds," whilst there is no means of obtaining anything like certain knowledge of the thickness or strength of such barrier? Where water may be expected from an adjoining colliery, the thickness of coal to be left as a barrier against the ingress of the water must depend in a great measure on the thickness of the vein and the strength and fracture of the coal, also on the kind of stone forming the roof and floor; if these consist of broken fossil shale, with threads or veins, or of soft clays, the water will be found to percolate through a considerable thickness of barrier; but if, on the other hand, these consist of hard, compact, siliceous grits, or any other kind of rock of durable texture, the quantity of coal left between the collieries need not be so great; thirty to forty yards of barrier is very commonly left between the workings of extensive collieries."

To prevent a surprise to the main body of an army advancing into an enemy's country, it is usual to throw out advanced pickets, who feel their way, so to speak, through the unknown dangers that may harm them; so, in mining underground, wherever it is known that water has collected in old and deserted mine workings, the position of which is not marked out in any plans, or, indeed, wherever it is desirable to keep a strict watch upon the inroads of water, such as working under a river or the sea, one or more exploring drifts, or small tunnels, must be thrown forward in advance of the main working places, and bore-holes kept about ten or twelve feet in advance of the faces of the drifts, as shown in the next cut. These borings give ample warning of the presence of the enemy, who is then attacked and routed with the aid of a proper system of drainage, which shall conduct the water to the *sump*

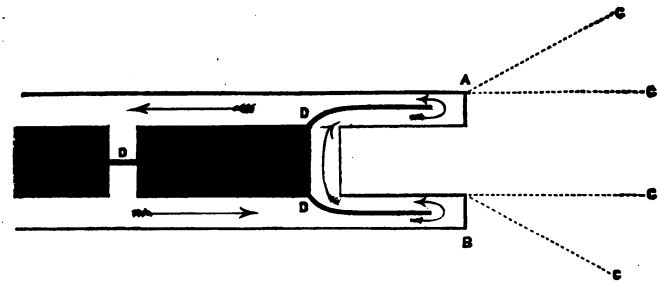


Fig. 197. The Pillar and Stall System. A, B. Main working-places. C, C, C, C. Exploring bore-holes. D, D, D. Brattices, or timber partitions to confine the air (shown by the arrows) in its proper channel, and make it sweep round the place where the men are working at A, B. The shaded parts represent the pillar left to support the roof.

or pump-hole, or the water is fairly shut out by clay dams, constructed by ramming clay between two strong partitions of wood forming a shield, which effectually secures the miner from his enemy water.

The construction of the bore-rods, depth of bore-holes, and formation of the dam are all minutely described in Mr. Greenwell's work on "Mine Engineering." A colliery or mine is said to be drowned when filled with water; and many instances are on record where from thirty to one hundred men and boys, with their horses, rolleys, and other working gear, have been suddenly destroyed by a rapid influx of water cutting off their escape by the main shaft.

It is in the construction of the pumps, valves, and steam-engines employed to drain the mines that the mechanical genius of the Englishman is apparent. The common suction-pump, so called, is not employed in the steady hard work required to keep a mine dry, but a pump first invented by Sir Thos. Morland, about two centuries ago, and introduced into the Cornish mines by Murdock. This pump is called the "Plunger force-pump," and it acts in the same manner as the solid plunger

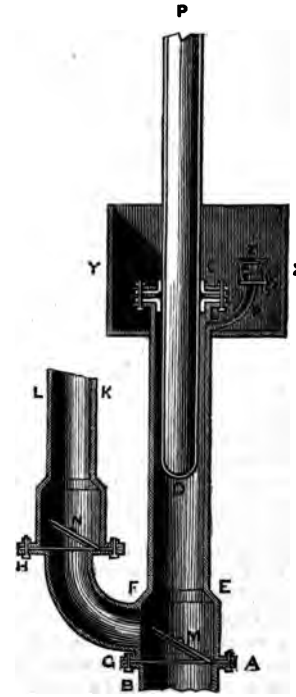


Fig. 198. The Plunger Force-pump.

used in Bramah's hydraulic press. Instead of a piston, which fits accurately the interior of a barrel- suction- or lifting-pump, there is a long cast-iron cylinder, P O, nicely turned and polished on the outside, and of a diameter somewhat less than the inside of the barrel. This cylinder, called the "*plunger*," slides through a collar of leather, D C, on the top of the barrel, so arranged that the plunger works air-tight. To prevent the leather from shrinking by drought, there is usually a little cistern, X Y, formed round the head of the pump, and kept full of water. The plunger is forced down by a rod from the connecting beam, which is attached by numerous clamping bolts to a single piece of pine fitted inside the cast-iron plunger. At the bottom the barrel of the pump is connected with two valves, G A M, and H I N, being respectively the inlet and outlet valves; so that when the plunger is raised, the valve, or door, M, opens and admits the water, whilst the valve N is shut; and directly the plunger is forced down again, the latter opens, and allows the water to pass up a pipe, L K, whilst the valve M is closed. The whole power of the steam-engine is used to pull up the plunger and connecting rod; and it is usual to divide the shaft of a mine into a succession of lifts, in which the water of the lowest lift is delivered to the pump next above it, and so on in succession until the water reaches the surface. The plunger-pump is used in all these lifts except the lowest, where the ordinary suction- or lifting-pump is used, with the view of obviating inconvenience, should the water, from derangement in the machinery or otherwise, rise so high in the mine as would make the valves and barrel of a forcing pump inaccessible, and also on account of the facilities afforded by the lifting pump in the drainage of the water as the mine is sunk deeper. The force of the engine is expended in lifting the pump-rods, and the water is forced out by the weight of the pump-rods in their descent. The pump-rods of some of the engines, however, are too heavy for the engine to lift, and part of the weight has to be taken off by one or more levers, provided with counterbalance weights, placed either at the surface or in some convenient side excavation. The main pump-rod of Davy's engine at the Consolidated mines is one-third of a mile in length, and weighs 95 tons: the other rods weigh 40 tons: making a total weight of 135 tons; of which 39 tons only are wanted to balance the water in the pump, and the greater part of the remaining 96 tons is balanced by weighted levers, or, as they are termed, "balance bobs." The main pump-rod is usually composed of balks of "Memel timber," and at intervals, down the sides of the shaft, projecting pieces are bolted on, which catch upon suitable timbers let into the sides of the shaft to prevent the rod from descending too fast, in the event of fracture above. The rod is guided at intervals by appropriate frames. "There is some-things," says Mr. Bourne (who explains the above), "rather primitive in these expedients, and it appears to us not improbable that the whole of this cumbrous apparatus will hereafter be superseded by machinery operating by atmospheric pressure, whereby the pump-rods will be rendered superfluous, and a small engine, working at a quick speed, will suffice."

The question of valves is, of course, one of great importance, and the size of the valve, in large pumping engines, was not formerly so carefully attended to as it is now. A large area in the valve-passages, for the water to flow through, in order that the power of the engine may not be expended in putting the fluid in motion to fill the pump barrel, is absolutely indispensable.

The steam-engines used to move the pumps are extremely rough at many of the mines; but in Cornwall, where fuel is comparatively dear, the greatest attention has been paid to the economy of coal. The gigantic cylinders, measuring sometimes ninety inches in diameter, with the valve, gearing, steam-pipes, &c., are all carefully protected from the cold by outside jackets composed of a non-conducting material; and the perfection of them is so complete, that the duty of the Cornish steam-engines is taken as a perfect example of the accumulation of "horse-power." The great Watt tested the powers of a horse by ascertaining the weight which a horse could lift over a pulley out of a well, and with him horse-power really meant what the words imported. Reduced to a unit of duty, "one horse-power" is equivalent to 33,000 pounds raised one foot high in one minute. The next cut, from Bourne's "Treatise on the Steam-engine," is a fine example of the construction of a steam-

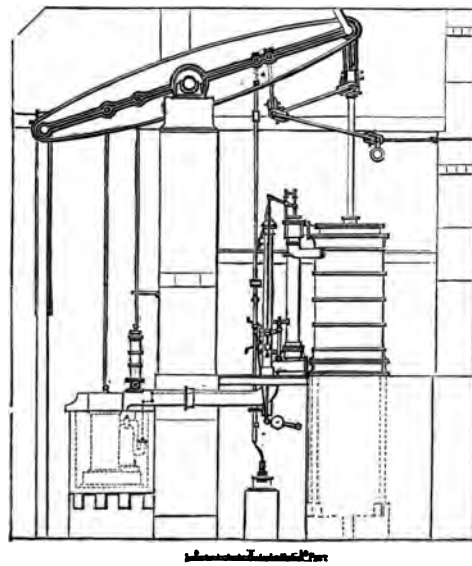


Fig. 199. A Cornish Pumping Steam-engine. (Bourne.)

engine used for pumping water out of a mine, and contrasts most amusingly with the contrivances employed for the same purpose some three hundred years ago.

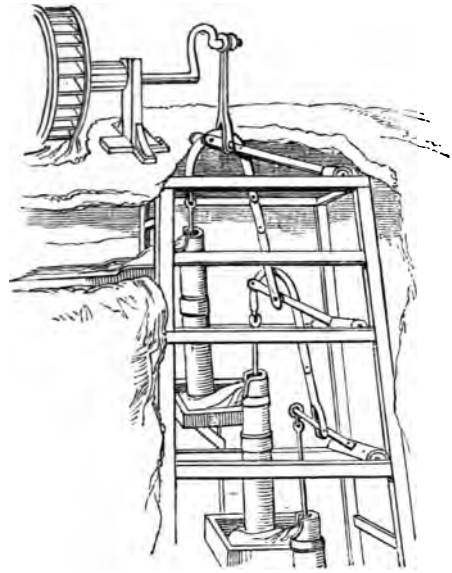


Fig. 200. Pumping Apparatus used three hundred years ago. (Agricola, 1550.)

In the Cornish engines, the consumption of fuel has been greatly decreased since the time of Watt, chiefly by the large application of the principle of expansion. In a cylinder engine erected at the United Mines, an average duty of 107,000,000 pounds raised one foot high by the consumption of one bushel of coals, weighing ninety-four pounds, was obtained, and this duty has been surpassed by others since its erection. The introduction of "*super-heated steam*" will doubtless effect still greater economical wonders in the consumption of coals.

With this digression on the subject of keeping mines free from water, we will return to the subject of the preparation and smelting of the iron ores.

Instead of washing the iron ore in the manner used in dressing the copper and tin ores, it is merely stacked in great heaps, and exposed for some months to the weather; during which time the outer crust or coating of the adhering and comparatively worthless gangue, or rock, cracks and falls off.

With very few exceptions, the next step is to roast the ore; this is performed in a very simple manner by mixing the ore with small-coal, which is set on fire much in the same manner as the London clay is now burnt in heaps in the clayey districts surrounding the suburbs of the great metropolis. By this process the water, the carbonic-acid gas, and sulphur, if any, are driven off, and the ore sustains a loss equal to about twenty-five per cent., and if examined after burning, is found to have assumed the form of a dark-red and partially porous mass, in consequence of the protoxide of iron previously united with the carbonic acid being converted into peroxide, Fe_2O_3. The amount of carbonate of iron in the ironstones associated with the coal measures varies from fifty to eighty per cent., the other constituents being silica, alumina, lime, magnesia, with minute quantities of sulphur, phosphorus, potash, and sometimes oxide of manganese.

If the ore consisted only of the peroxide of iron, carbon in the shape of coal or coke would be sufficient to reduce it; but, since the ore contains a large quantity of earthy matter, the particles of iron, when reduced, would be held in this porous earthy mass like water in a sponge, and, although reduced, the metal would remain in an unavailable form. Something must therefore be mixed with the roasted ore for the purpose of liquefying the earthy matters, and the cheapest and most convenient flux is of course limestone. The lime of this substance forms a rough kind of slag or glass with them, and liberates the iron, which gradually sinks to the bottom of the great furnace, whilst the liquefied slag floats on the surface of the heavier iron like oil on water, and is let off by a tap-hole placed higher up than the orifice from which the liquid iron flows out.

Dr. Percy, of the Museum of Practical Geology, has made a vast number of analyses of the *slags* from iron furnaces, and he reported in 1846 to the British Association the results of his experiments.

These slags were found to contain silica, alumina, lime, magnesia, protoxides of manganese and iron, potash in small quantity, and sulphur as sulphurets; phosphoric acid was also found in some of them. The production, under the peculiar circumstances in which these slags were formed, of crystalline minerals, in many respects similar to *some which are found in nature*, renders the inquiry into their chemical constitution and physical conditions a peculiarly interesting one; and in its bearings upon many geological phenomena it is most especially so, as showing the influences of the long-continued action of high temperature upon mineral combinations and crystalline structure. With respect to cast-iron, which will be spoken of more particularly in other parts of this chapter, a most interesting account is given by Professor Hunt of the origin of the famous "Berlin cast-iron." At the time when the final struggle commenced between Prussia and Napoleon, the patriotism of the Prussian ladies was particularly conspicuous. With the noblest generosity, they sent their jewels and trinkets to the Royal Treasury to assist in furnishing funds for the expenses of the campaign. Rings, crosses, and other ornaments of cast-iron were *given in return* to all who

made this sacrifice. They bore the inscription "*Gold von eisen*" (I gave gold for iron). Such Spartan jewels are, to this day, much treasured by the possessors and their families.

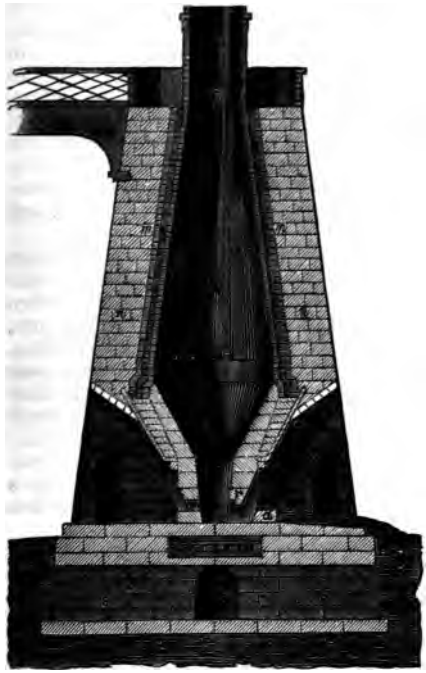


Fig. 201. Section of a Blast Furnace (Muspratt). m, m, m, m. Two courses of fire-brick. *l*, *l*. The bad-conducting casing. *n*, *n*. Outer casing of solid masonry. B. The crucible where the melted iron and slag collect, the bottom of which is called the hearth, formed of a large firestone supported by masonry, having air-channels, with open arches, F, F, F, to keep the whole dry. D. The chimney, approached by a gallery, and gang-way, with an opening to admit the fuel, &c. C. The throat or tunnel hole. A. The cone or body. B. The boshes. E, E. Arches leading from one side of the furnace to the other. E. The tymp, a stone which does not reach the base and is supported by strong iron-work. A. The dam-stone. C, C. Perforations a little above the level of the tymp, to admit the pipes or tuyeres conveying the blast of air from three pipes.

The furnace used surpasses in size all others that have been previously described, and is from forty-five to fifty feet high, being called the blast-furnace because it is fed with a constant and powerful current of air forced through the burning material by proper blowing machines. The interior of this furnace, technically called "the shirt," consists of the very best fire-bricks, about fourteen inches thick. The exterior is built of stone or brick, within which is a casing of masonry or fire-bricks, about fourteen inches thick. Between the interior and exterior walls is a space of about six inches, which is tightly rammed with a bad-conducting material, such as river-sand, brick, and scoriæ. No expense or care is spared in building these furnaces, which are never allowed to burn out until they want repairing; so that a well-built furnace will last from five to ten years, provided an unforeseen accident (arising from carelessness in the adjustment of the proportion of the ore, fuel, limestone, and blast of air to each other) does not take place.

	Feet (height).	Feet (width).
The crucible on hearth . . .	6 to 6½	bottom, 2 to 2½; top, 2½ to 3
The boshes, inclined at an angle of from 52° to 59°	7 to 8	12½ to 13½
The cone or body. . . .	30½ to 36	
The chimney or mouth . .	8 to 12½	3½ to 4½

The next cut shows the arrangement of the tuyeres or blow-pipes, the nozzles of which are made hollow and kept cool by a current of cold water. The air is forced in by an air-pump, and it has been calculated by Dr. Percy that no less than *six tons* of air pass through an average-sized iron blast-furnace every hour. Before passing from the tuyeres, the air is now usually heated to a temperature of about 600° Fah., by passing it through coils of red-hot pipe. With this "hot blast" it is stated that an increase of about one-eighth, or of 360° of heat, are obtained in the furnace. The "hot-blast" was first introduced by Mr. Neilson about thirty years ago; it has certainly effected a great saving of fuel, and in many cases enabled manufacturers to increase their weekly production of iron fifty per cent.; but the following observations of Mr. Henry Hartop, of Doncaster, addressed to members of the engineering profession, are worthy of notice; and the paper is dated April, 1847:—

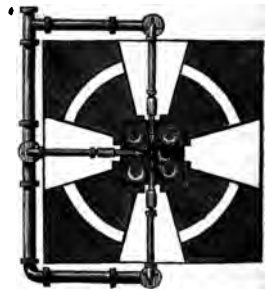


Fig. 202. Ground-plan, showing the disposition of the *tuyere* pipes.

"*A View of the present State of the Cold- and Hot-air-blast System of manufacturing Pig Iron in the Smelting Furnace, as practised for the last eighteen years.*—Notwithstanding great skill and attention have been used during the whole of this period, the produce from the latter has regularly fallen in the market until it has reached a difference as compared with iron of a similar quality made with cold air, of from 1*l.* 15*s.* to 2*l.* per ton; for the particulars of which, see the 'Mining Journal' for the last and present year; although the most unprincipled means have been taken to uphold the price, as the following notices in the 'Mining Journal' of November 21st and December 15th, 1846, respectively will testify:—

"'*Hot- and Cold-blast Iron.*—A correspondent in Newcastle writes as follows: Mr. R. Stephenson, the eminent engineer, has been making a series of experiments upon the relative strengths of hot- and cold-blast iron, the result of which will be a complete revolution in the iron trade. Hitherto cold-blast iron has brought a higher price, and has been considered in every respect superior to hot-blast. Previous, however, to the construction of the High Level Bridge at Newcastle-upon-Tyne,

intended to connect the York and Newcastle with the Newcastle and Berwick Railway, Mr. Stephenson caused more than one hundred experiments to be made with the various sorts of pig iron, the result of which has been to prove that hot-blast is superior to cold- in the proportion of nine to seven; and, moreover, that pig iron No. 3 is better than No. 1, which, up to this time, has sold much higher in the market. —November 21st, 1846.'

'Gateshead Iron Works, Gateshead, Dec. 15th, 1846.

"'*Hot- and Cold-blast Iron.*—Sir, I beg to inform you, and those who may be interested in this subject, that the article which appeared in your excellent journal of the 21st of November, from a Newcastle correspondent, purporting to be the result of experiments made by Mr. R. Stephenson, the eminent engineer, on the relative strength of hot- and cold-blast iron, is entirely fallacious and unauthorized. As is evident, your correspondent has reference to the experiments which are now being made under my superintendence, by direction of Mr. Stephenson, at these works. It may be proper to state, that they were adopted with a view to the selection of the most suitable iron to be used in the construction of the High Level Bridge. These experiments are as yet by no means completed; indeed, the number hitherto made does not amount to that stated by your correspondent; but, so far as they have gone, no one at present, except myself, is in possession of them, so as to be enabled to draw a just estimate from the average results. It must therefore be clear that, from whatever source your correspondent has obtained his information, it was not only premature but incorrect. Your insertion of this in your next journal will assist to correct any erroneous impressions that may have been formed by your readers relative to these experiments, and at the same time oblige

"'Yours, &c., JOHN HOSKING.'

"Since the publication of my paper on this subject in the 'Mining Journal' of August 6th, 1842, many circumstances have occurred corroborative of what I therein state, of which I may here add, that—

"An engineer and iron founder on the most extensive scale in Lancashire, previous to his death, a short time ago, gave an opinion to the effect that, within the three previous years more machinery in mills and other manufactories had broken down in his district than in the twenty-five years preceding, in consequence of using hot-blast iron. The same is doubtless the case in other manufacturing districts; as in Yorkshire some of the largest foundries, where it is known that none but the best cold-blast iron is used, are in a great measure employed in replacing castings, &c., for those constantly breaking.

"In Staffordshire, at a furnace supplying a bar-iron work with pig iron, the proprietors thought it worth their while, without any intimation to their customers, to use one out of three blast pipes with hot air, by which the previous good name of the wrought iron made from pig iron, the produce of cold blast only, from the same furnace, was at once destroyed.

"At that notoriously unfortunate mill at Oldham, which fell before

being finished, and by which so many lives were lost, it is but too well known that every cast-iron bearer in the building was found broken, the contract for making which bound the founder to use one-third of Staffordshire iron and two-thirds of Scotch, nine-tenths of which is made with hot air; and notwithstanding from the above and many similar misfortunes, it is but too well known that the iron in question is altogether incapable of bearing impact, yet we even now see contracts for railway chairs being advertised for, in which the above mixture of iron it is stipulated shall be used; and when this very inconsistent practice is named to the parties implicated, the only reply made is, 'How can it be proved that the chairs found broken after almost every railway accident, whether the chair found so broken was the cause of such accident, or in consequence of it?' This, I am very happy to find, is at length bringing about its own cure; and such railway companies as have any regard whatever for public safety are becoming their own founders, with a view to prevent so unfit a material being used for railway purposes under their management.

"I shall now only add, as I stated in the paper in question at pages 9 and 10, nearly five years back, that the public only can remedy this very great evil, inasmuch as the greater the difference in price between strong and weak iron, the greater the inducement for the founder to use the latter whenever he is allowed to do so."

Muspratt remarks: "It would appear that greater benefits have been derived in Scotch than in English furnaces, by the introduction of the hot blast, either owing to the former having been worked less economically than the latter, previous to the introduction of the hot blast, thus making the saving appear greater; or else the fuel used in Scotch furnaces being weaker than the English, the hot blast has consequently effected much greater comparative advantages."

A front view of one of these great, heavy-breathing, giant blast furnaces impresses the observer with something like awe; and if he waits till night comes on, he is still better able to appreciate the grandeur of the scene in the lurid and ever-changing blaze which proceeds, volcano-like, from the mouth of the fiery furnace. Some idea of the quantity of materials used, and the iron obtained from a single furnace in one week, may be gained from Dr. Noad's account of the work performed by a furnace at the Cwm Celyn and Blaina Works in South Wales—

From 652 charges of roasted iron ore, coal, coke, limestone, and forge cinder } iron made, 181 tons 9 cwt.

	Cwt.
Each charge consisted of coal . . .	10
Coke	6½
Limestone . . .	1
Roasted iron ore .	10
Red ore . . .	1
Forge cinder . .	4
Total	32½ × 652 = 1059 tons 1 cwt.

So that from 1059 tons 1 cwt. of ore, coal, coke, limestone, and cinder there were obtained 181 tons 9 cwt. of pig iron; and taking Dr. Percy's calculation of the consumption of air at six tons per hour, day and night, for the week of seven days, the quantity of air used amounts to the astounding quantity of 1008 tons weight; the tonnage of the air and the raw materials used being nearly equal to each other.

After a furnace is built, it is allowed to stand for some months to settle and dry spontaneously; and the important step of lighting the furnace is commenced by piling a quantity of loose fuel outside the furnace—viz., in the arch forming the breast. The fire, smoke, and

Fig. 203. The Tapping of the Blast Furnace.

heated air enter the furnace at the orifice left between the *tymp* and the bottom of the crucible or hearth, as the damstone at this point of the operation is left quite open. The fire is maintained for several days and nights, and when the lower part of the brickwork and masonry has become sufficiently warm, fuel is thrown in at the chimney, or mouth, till it reaches the middle of the boshes. In a few days more, the furnace is entirely filled with coal or coke, and in about fifteen days, or three weeks, from the time of first beginning to light it, the blast of air is cautiously set to work, and when the fuel has sunk down to a certain point, a little roasted iron ore is thrown in; then more fuel, more ore, flux, and fuel, until the whole of the interior is filled with the necessary materials in the right proportions, and then the blast is urged to its full power, and the smelting fairly begins. As the fuel, ore, &c., sink down, their places are immediately filled up with fresh materials, the only rule being to keep the blast furnace quite full. In about twelve hours the contents of the crucible are run off, the blast being frequently suspended at this time. The slag, or cinder, is allowed to run as an overflow into cast-iron moulds, to be used for building purposes; and these lumps of slag are called "donkeys." The lower hole is then tapped, and the liquid molten iron, which throws up streams of brilliant coruscations and sparks, flows out in a gradual, one might almost say, dignified manner, filling up a large number of rough sand-moulds placed in front of the blast furnace. These moulds consist of parallel trenches, connected by a main channel. The iron assumes the form of semi-cylindrical bars called "pigs," connected together by those of larger dimensions termed "sows," from which they are subsequently separated.

The eminent authority, Truran, thus briefly describes the changes which take place inside the furnace, unroasted ore being used: "The changes which occur in the descending ore commence with the uncalcined ores in the throat of the furnace; they lose their moisture and volatile gases before they reach the level of the boshes, absorbing from the fuel the necessary caloric for calcination. Below this the ore is gradually converted from a sesquioxide (Fe_2O_3) to a magnetic oxide (Fe_3O_4), or, as sometimes occurs, into metallic iron, having combined with a portion of the carbon from the fuel to form the fusible carbide of iron. From the bottom of the boshes to the level of the tuyères the reduction of the ore and flux into a liquid mass is completed. The fusion of the ore and flux occurs at a height of eight or ten inches above the tuyères, from whence it descends into the hearth. Here the metal, from its greater specific gravity, falls to the bottom, freed more or less from the fluid cinder, which floats on the surface and protects it from the oxidizing influence of the blast."

No new light was thrown on the theory of the blast furnace until Professors Bunsen and Playfair made their interesting experiments with the gases evolved from the incandescent materials at the various parts of the interior of the blast furnace. It would be impossible here to do full justice to the voluminous facts recorded by those learned chemists; but the main facts are, that,—

1. There is no carbonic-acid gas in the immediate proximity to the tuyères, but an abundance of carbonic-oxide gas, which would have a strong deoxidizing power.
2. Cyanogen and cyanide of potassium are formed at about or near the blast. The cyanogen being obtained by the direct union of the carbon of the fuel and the nitrogen of the air of the blast, whilst the potash is derived from the ashes of the coal, and likewise from the iron ore. Cyanide of potassium has long been known for its powerful deoxidizing qualities; and this chemical agent no doubt performs most important functions in the general process of reduction.
3. Ammonia is liberated in large quantities, and Bunsen and Playfair have recommended that it should be collected, as they calculated that each 280 cwt. of coal, used every twenty-four hours, would furnish ammonia sufficient to make 200 lbs. of chloride of ammonium, or sal ammoniac.

The constituents of the gases evolved from the blast do not appear to have been as yet applied to any useful purpose, but the heat and imperfectly burnt gases are no longer permitted to escape; and in the best conducted iron works the 81⅓ per cent. of heat formerly wasted in the air is now conducted, by large pipes six feet in diameter, lined with fire-brick, under proper boilers; and at the Cwm Celyn works the gases from two furnaces only more than suffice for the supply of seven boilers, and for the heating of the hot blast for both furnaces, at a saving of full 10,000 tons of coal per annum.

The cast or pig iron is not, however, sufficiently pure and malleable to be employed in the smithy, or in larger operations, and the impurities it contains may be understood by consulting the following analysis of pig iron smelted in Scotland with coal:—

Iron	93·6
Carbon free	1·4*
Carbon combined	1·2*
Silicon	1·5
Sulphur	·4
Phosphorus	·4
Manganese	·5
Slag	1·0
	100·0

It is evident from the above analysis that the iron contains 6·4 per cent. of foreign substances, of which the sulphur and phosphorus, the silicon, and excess of carbon must be got rid of before the iron is fit for useful purposes, such as railway bars and other important castings. This analysis is not an exceptional case, as may be noticed in the following

* Special notice should be taken of this constituent, in order to understand the principle of Bessemer's process.

analyses, made twenty years ago, by the author, of Blaernarvon pig iron and of Coalbrookdale, Salop, pig iron:—

	Blaernarvon.		Coalbrookdale.
Iron	90·39	...	91·10
Carbon, free and combined	4·50	...	5·23
Silicon	2·10	...	1·90
Phosphorus	1·04	...	·32
Sulphur	·44	...	·13
Manganese	1·40	...	1·20
Aluminium	a trace	...	·10
Loss	·13	...	·02
	100·00	...	100·00

It is the object of the *refining* and *puddling* processes, with the aid of mechanical appliances, such as hammers and rollers, to get rid of the chief portion of the impurities and obtain good commercial bar iron. The refining process consists in directing streams of air from six tuyères upon the surface of the bath of liquid iron, so that a portion of the iron is oxidized, and, combining with the silicon, also oxidized into silica, forms a silicate of iron, which floats upon the surface of the refined metal. This slag exercises a strong decarbonizing action on the iron, and when the air has been directed for a sufficient time upon the molten iron and the slag floating upon the surface, carbonic-oxide gas escapes, showing the nature of the action that proceeds; finally, the iron is run off by a tap-hole, and a fresh portion of crude pig iron immediately placed into the refining furnace.

The process of refining is now generally abandoned in Staffordshire, the same objects being attained much more economically by the improved method of puddling termed boiling. The following analysis, by the author, of a specimen of cinder from "boiled pig iron" will give some idea of the amount of purification by this process, and of the substances removed from the iron:—

Protoxide of iron	78·1
Protoxide of manganese	2·96
Silicon	14·6
Phosphate of aluminia	·8
Phosphoric acid	2·85
Sulphuric acid	·88
	100·19

The final purification of the refined iron takes place in a reverberatory furnace by a process originally invented by Henry Cort, who was born at Lancaster, 1740. This unfortunate gentleman, says his biographer in the *Bristol Mercury*, "became an iron merchant at Gosport, in Hampshire, and after erecting works at Fontley, near Gosport, and expending 20,000*l.* in experiments, it then became necessary to obtain a moneyed

partner, and he found one in Mr. Adam Jellicoe, chief clerk in the office of the Paymaster of the Navy. Mr. Jellicoe was a man of reputed honour and wealth, and he made such a bargain with Henry Cort as showed the very great advantages which wealth can command. He advanced, from time to time, 27,500*l.* to the firm, for which he was to receive five per cent. interest, half the profits of the trade and patents, and a salaried appointment for his son at the iron works. The ingenious Mr. Cort having at length succeeded in effecting one of his objects, took out, in 1783, a patent for its manufacture, specifying the patent as for 'malleablizing cast iron in the air furnace by the cheap flame of pit coal, without charcoal, blast, bellows, or cylinder.' In the following year Mr. Cort showed that he had made still further progress, for he then obtained a second patent, and this time it was for a grooved or fluted roller, by means of which the large masses of iron at a welding heat obtained from his puddling furnace were almost instantaneously elongated into bars, instead of that result being effected by the tedious and imperfect previous operation of shaping a rough mass into a square and lengthened figure by incessant blows of a hammer.

"Without noticing further, for the present, the great importance of these new processes, we now mention that when, in 1784, Mr. Anthony Bacon, having made an ample fortune, sub-let the mineral tract of forty square miles of moor and mountain surrounding Merthyr Tydvil, a lease of which for ninety-nine years, at the trifling rent of 200*l.* a year, he obtained in 1755, Mr. Richard Crawshay became the lessee of the Cyfarthfa and Mr. Samuel Homfray of the Penydarran 'flitches,' as they have been called, 'of the great Bacon domain.' At Cyfarthfa Mr. Crawshay was laboriously forging his ten tons of iron per week when he chanced to hear of Cort's inventions, and in 1787 he paid a visit to what he described as 'the little mill at Fontley,' and forthwith engaged with Mr. Cort for the erection of puddling furnaces and grooved rollers at Cyfarthfa. The works were duly completed, when, instead of ten tons, Mr. Crawshay could with ease turn out two hundred tons of excellent bars per week; and Mr. Homfray, soon perceiving the importance of the new inventions, borrowed from Cyfarthfa the drawings of the puddling furnaces, the patterns of the rollers, and Mr. Cort's workmen to teach the operations. Contracts were then signed by Messrs. Crawshay and Homfray to pay Mr. Cort 10*s.* per ton of bar iron as the licence dues for the use of his two patents.

"Everything thus seemed, in 1789, as smooth and clear as an Italian lake, and Mr. Cort had the fairest prospect of realizing a large fortune for the benefit of himself and his increasing family. In that year, however, Mr. Jellicoe, his partner, suddenly deprived himself of life, and, to all men's astonishment, he turned out to be a public defaulter; the 27,500*l.* which he had advanced to the partnership, on the terms above narrated, having—according to the affidavit of Mr. Alexander Trotter, Paymaster of the Navy—been moneys entrusted to his deputy Jellicoe for the discharge of seamen's and other wages. Mr. Trotter then began to play a part the occult ramifications of which we cannot

here attempt to unfold; but they undoubtedly connected themselves with that series of transactions for which William Pitt's bosom friend, Henry Dundas, Viscount Melville, was impeached by the House of Commons in 1805. Had grace and time been allowed, Cort would have had no difficulty in supplying Jellicoe's deficiency. He was engaged on lucrative contracts for the navy; the Cyfarthfa and Penydarran mills were approaching completion; other ironmasters had made and signed similar contracts with the patentee; and very large returns from the patents were certain. Only fair and reasonable, then, would it have been to have taken the security of Cort's licence-dues for the repayment of his partner's default. But what did Trotter? He forthwith sued out the Star Chamber process of an extent in aid against poor Cort's effects upon an affidavit in which he swore that he had been informed Cort's prospects and credit were 'much decayed,' so much so that the summary process taken by the Paymaster of the Navy was required in order to prevent a total loss of the default! A disastrous sale of the Fontley iron-works was the consequence. They produced only 16,000*l.*; and, although a jury valued the goodwill of the establishment at 20,000*l.* more, it was declared that a debt of 11,000*l.* remained in the hands of the Crown, for which alleged deficiency Cort's patents and contracts with the Welsh ironmasters were seized and locked up in the desk of the Solicitor to the Navy Board. Thence, it is believed, they never issued to the light of day until they were exhumed to be burnt, along with heaps of other documents that had each a precious tale to tell, when Lord Melville and Trotter mutually agreed to adopt that process—for what purpose, viewed in connexion with Melville's subsequent impeachment, we need scarcely specify. Cort was of course a ruined man—the victim of deception on every side, and, it seems, purposely made a victim in order to varnish over for a few more years the fading characters of other people. Although, however, the patents were no longer produceable, most people will be disposed to say that surely the Welsh ironmasters, who were profiting immensely through the agency of Cort's inventions, ran not back one iota from their word. Alas for weak humanity when opportunity serves further to enrich the already rich!—the workers of Cort's patents, bound by deed to faithfully recompense him for the same, did not give Cort a shilling of the licence-dues which they had legally and morally bound themselves to pay!

"Henry Cort's inventions not only enriched many individual firms, but they were immensely advantageous to the nation. From this time British iron superseded foreign iron for all our naval purposes, thereby saving one and a half millions a year previously paid to the iron makers of Sweden and Russia. It is asserted, too, that the railway system was rendered possible solely by Cort's invention of the grooved rollers. Taking these asserted facts into account, the total saving from the two inventions, in railways and in home-made iron, is estimated at 500,000,000*l.* since they came into operation in 1785, besides the yearly saving of 60,000,000*l.* now progressing. Let it be remembered, too,

that Cort mainly suffered loss through the malpractices of individuals in the service of the British Government which existed in his time."

Cort's puddling process consists in liquefying the refined metal with some cinder rich in oxide of iron on the hearth of a reverberatory furnace, and at particular periods of the operation stirring and raking the mass about until the metal, at first very liquid, becomes doughy, and emits numerous bubbles of carbonic-oxide gas. Experience alone guides the puddler as to the precise moment when the metal is to be raked together and formed into masses called *puddled balls* or *blooms;* and all this time the workman, almost in a state of nudity, has to face the intense heat and glare of the furnace, so that, as he proceeds with his labour, the perspiration falls from him in such quantity as to produce a distinct wet circle round the place where he stands. The *blooms* are then conveyed to a great hammer, or, still better, to a Nasmyth's steam-hammer, where, by repeated blows, the slag is fairly squeezed out, like water from a sponge; it is then passed through heavy rollers, where it is rolled into bars, and these, when cold, are broken into short lengths, again heated in a reverberatory furnace, hammered, and rolled, to form the ordinary British bar iron. In the puddling process there is, of course, considerable loss, and it is now considered that 22 cwt. of pig iron is required to make 20 cwt. of puddled bars, and about 21½ cwt. of puddled bars to make 20 cwt. of the finished merchant iron. Some idea of the improvements effected in the puddling process may be formed from the fact that in Cort's time 33 cwt. were required to produce the same quantity of merchant iron now made from 24 cwt. of pig iron.

Messrs. Calvert and Johnstone have made a careful series of researches on the changes that take place in the composition of pig iron, when converted into bar iron, by which it is clearly proved that the quantities of carbon, silicon, phosphorus, and sulphur are reduced to a minimum by the puddling process, and that the hammering, squeezing, and rolling assist in the segregation of the carbon and silicium.

Since Cort's great invention, which completely revolutionized the iron trade, of course many other processes have been proposed by inventors, who have all sought to shorten the steps of the process required to convert pig into malleable iron or steel. Amongst the most notable processes are those of Plant and Martin. Mr. Clay's process is so ingenious that it deserves special notice even in the present work, which professedly deals with this extensive field of inquiry only in a popular manner.

By the ordinary method, malleable iron is obtained from the ore by six processes—viz.,

1. Calcining the ore.
2. Smelting in a furnace, by the aid of blast, either cold or heated, with raw coal or coke for fuel, and limestone as a flux.
3. Refining the "pig" into "plate" iron.
4. Puddling, shingling, and rolling to produce the "rough," "puddled," or No. 1 bars.

5. Cutting up, piling, and rolling, to produce "merchant," or No. 2 bars.
6. A repetition of the same process to make "best," or No. 3 bars.

Mr. William Neale Clay proposes to diminish the number of manipulations by grinding together a mixture of rich iron ore, such as hæmatite, with about four-tenths of its weight of small coal, so as to pass through a screen of one-eighth of an inch mesh. This mixture is placed in a hopper fixed over a preparatory bed or oven, attached to a puddling furnace

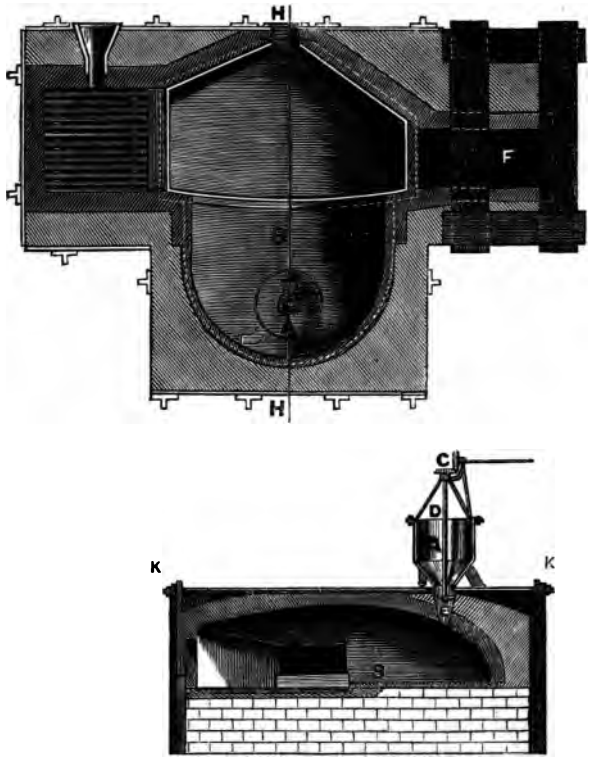


Fig. 204. Mr. Clay's Oven and Puddling Furnace. A. The hopper to contain the charge of ore and coal. B. Preparatory oven or bed. C. Wheels to regulate the supply of the mixture. D. Shaft to which the perforated bottom B is attached. F. Chimney, nearly double in area to that which is required on the old system of puddling. The sectional drawing, K K, is taken through H H.

of the ordinary form. While one charge is being worked and balled, another gradually falls from the hopper through the crown, upon the preparatory bed, and becomes thoroughly and uniformly heated; the carburetted hydrogen and carbon of the coal combining with the oxygen of the ore, advances the decomposition of the mineral, while, by the combustion of these gases, the puddling furnace is prevented from being injuriously cooled. One charge being withdrawn, another is brought forward, and in about one hour and a half, the iron is "balled," and ready for "shingling" and "rolling." Mr. Clay states that the cinder produced is superior in quality to that which results from the common system; it contains from 50 to 55 per cent. of iron, and is free from phosphoric acid, which is so injurious in ordinary slags—vide next analysis (by author) of slag cinder from common puddled iron. The phosphoric acid chiefly arises from the limestone, nearly every specimen of which contains a minute proportion.

Protoxide of iron	78·40
Protoxide manganese	2·96
Silica	14·00
Phosphate of alumina	·80
Phosphoric acid	2·85
Sulphuric acid	·88
	99·89
Loss	·11
	100·00

When Clay's cinder is re-smelted, it produces as much No. 1 and No. 2 cast iron, and of a good quality, as the ordinary "black band" ore of Scotland. The cast iron produced from the slag (amounting to one-third of what was originally contained in the ore) is mixed with the ore and coal in the puddling furnace; and thus, while nearly all the iron is extracted from the ore, as much wrought iron is produced in a given time, and at the same cost of fuel, as by the old system. The iron thus produced is stated to bear a high polish, is very uniform in its texture, is ductile and fibrous, having more than an average amount of tenacity, and at the same time appears to be more dense, as it possesses a peculiar sonorousness resembling that of a bar of steel when struck.

The new process, however, which for the time eclipsed the renown of all others, is that of Bessemer, and it is perhaps one of the misfortunes of an inventor, that if a palpable and popular advantage is apparently to be obtained from his discovery, that the public is rather too hasty in lauding the invention to the skies, and awarding to it praises for imaginary advantages which the inventor has never claimed. It is to do everything, and, like gutta-percha,—which was overdone with praises and declared good for every purpose, not even excepting, as "Punch" said, coughs, colds, and bunions,—the new process of Bessemer was at once to carry everything before it, and completely revolutionize the whole

iron trade, and really the arguments in its favour were so good that every one at once saluted the inventor as the future "richest commoner of England;" but a few analyses of the iron obtained soon pointed out the presence of the old enemies to the perfection of iron—viz., phosphorus and sulphur; and after this fact was known, the process was as unfairly depreciated as it had been formerly overrated; people will not include the element time in their calculation, and remember that the best invented processes may still be improved.

Bessemer's process no doubt will, *in time*, effect great improvements in the iron manufacture, and the author, in common with many others, has ever been a firm believer in its ultimate success, because the principle is good; at least, so far as the removal of the excess of carbon and silicon is concerned; and the very success of this part of the process is suggestive of others, by which the sulphur and phosphorus might be removed. What can be more simple than forcing air through a vessel lined with fireclay and filled with molten iron, and producing a most intense heat by the actual combustion of the carbon contained in all cast iron to the extent of nearly five per cent.? This operation is effected in an apparatus such as that depicted in the next cut, Fig. 205.

Mr. Bessemer's apparatus may be described as a clay crucible, or iron vessel lined with fire-clay, and pierced with holes, or fire-clay tuyères, beneath the surface of the molten metal, through which holes hot or cold air is forced at such a pressure as to hold the melted iron suspended in it, or to force it away from the air-passages; the air so forced in gradually increases the heat of the metal, and forces up the slag or cinder in a scum, which bursts and overflows like an exploding volcano, till the heat, having gradually burnt and purged away the carbon, oxygen, and silicon, leaves the iron malleable, though, by reason of its great heat, still fluid, and when run out into a mould and set, convertible into forged or bar iron without further process.

Up to this period the make of iron was a "puddling" process, and the distinctive appellations henceforth of those before the era and after will be "puddlers" and "non-puddlers," the stagnant and the flowing.

"A practical ironman," writing on the subject of Bessemer's process, says, "There are two processes by which pig iron is converted into malleable. In one process the 'pig' is first converted into refined metal, and the refined metal is puddled, and by the refining and puddling combined, the pig is converted into malleable iron. In the other process, the pig iron (without being refined) is converted into malleable by what is technically termed 'boiling,' which is, in fact, very similar to puddling. After being treated in one of these ways, the puddler forms the iron (which is then in the puddling or boiling furnace, of a pasty consistency) into masses termed 'balls,' of about eighty pounds each; and these, taken from the puddling or boiling furnace, are delivered to the 'shingler,' who shapes them into 'blooms' by passing them under the forge hammer or squeezer. The blooms are then passed through the rolls. First the roughing and then the finishing puddle bar rolls, and a finished puddle bar of malleable iron is produced. To convert the puddle-bar

iron into merchant iron it is cut into lengths, which are piled together and heated in a reverberatory furnace, and then rolled into the kind of iron required.

"Mr. Bessemer's process supersedes the refining and puddling or boiling processes now used, but not, of course, the use of the hammer

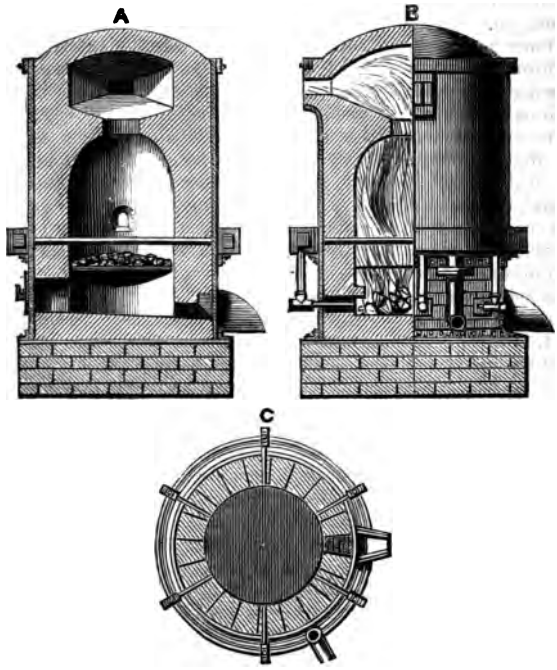


Fig. 205. A, B, C. Sections of Bessemer's apparatus, showing the construction of the iron vessel lined with fire-clay, and the arrangement of the tuyères.

or squeezer and rolls. Mr. Bessemer's 'ingots' are in precisely the same condition (except that they are much freer from impurities) as the 'balls' above referred to when delivered to the shingler. Both the 'balls' and Bessemer's ingots are malleable iron, but without the fibre or grain required for merchant purposes. This is produced by the hammering or squeezing and rolling through which both the 'ball' and the ingot have to pass. That Bessemer's process must succeed is at once evident to any one practically acquainted with ironmaking, as the *rationale* of the puddling or boiling process is to get rid of the excess of

carbon and the impurities in the pig iron, by exposing every part of it, in a melted state, to the action of the atmosphere. To effect this, the 'puddler' with great labour works it about with an iron bar while it is in the puddling and boiling furnace until every portion of it has been sufficiently exposed to the atmosphere, the oxygen of which combines with carbon in the iron and the other impurities, and carries them off. From this description of puddling it will at once be seen that Bessemer's process is, in fact, puddling upon a superior plan, as it is obvious that the iron in Bessemer's process is far more effectually acted upon and purified by the columns of air permeating every part, than by the imperfect mode of exposing each portion of the liquid iron to atmospheric influence by the tedious process of moving it about with an iron bar. The statement in a Birmingham paper that a particular bar, rolled from one of Bessemer's ingots, was 'red-short,' proves nothing one way or the other, as a great deal of iron made under the old process is 'red-short.' 'Red-shortness' depends upon the quality of the ore from which the iron is smelted, and cannot be remedied by any known process, unless, indeed, Bessemer should effect it. Calcareous and siliceous ores commonly give the iron produced from them a 'red-short' quality.

"The magnitude and importance of this discovery of Mr. Bessemer can scarcely be exaggerated. The only paralled to it is to be found in the kindred inventions of Henry Cort, which, towards the close of the last century, relieved this country to a great extent from its commercial servitude to Russia and Sweden in regard to its supply of wrought iron. Two years have been spent by Mr. Bessemer in the perfection of his scheme; and when, the other day, he divulged it to the world before men distinguished for their scientific attainments, and practical manufacturers well able to appreciate its vast public significance and its whole bearing on the trade in which they are interested, it took them wholly by surprise, superseding, as it does, the expensive, laborious, and tedious processes now in use in the production, and the application in some cases, of malleable iron and steel in this and many other countries, cheapening those articles to an extent which will lead to their employment, and especially steel, for purposes to which they have never yet been subservient, and in many respects refining and improving the quality of the metal. Men like the two Rennies, Nasmyth, and others of minor note, but of great experience as engineers and iron manufacturers, have pronounced emphatically and without qualification in its favour; while some, including Nasmyth, declare themselves unable to foresee the whole of the advantageous results calculated to spring from its discovery, not to this country alone, but wherever else it may be brought into use. It is to the credit of the Emperor of the French that, when the invention, then in an imperfect state, was brought under his notice within the last year, and when he comprehended its full import from personal interviews which he graciously conceded to Mr. Bessemer, he afforded him great facilities for conducting his experiments to a successful result, and has since intimated his intention of bringing the plan into practical operation in the arsenal at Rouelle.

"The essential feature of Mr. Bessemer's invention is, that he takes crude iron directly from the ordinary blast furnace, and in the incredibly short space of thirty minutes converts it into ingots of malleable iron or steel of any size, and fit for the various manipulations ordinarily employed to adapt them to all the material purposes to which they are now applied. He thus dispenses with all the intermediate processes to which recourse has been had to produce the same effect within the last seventy years, including the making iron into pigs, and the refining, puddling and squeezing stages, with all their attendant labour and fuel. Paradoxical as it may seem, it is not the less true, that he has achieved this great result by the application to the iron, in its transition from the blast furnace to the condition of the ingot, of a heat inconceivably intense, generated without furnace or fuel, and simply by blasts of cold air. By this means he not only avoids the injurious action of mineral fuel on the iron under operation, which has always deteriorated the quality of English iron, but saves all the expense of the fuel. He sets out with the assumption that crude iron contains about five per cent. of carbon; that carbon cannot exist at a white heat in the presence of oxygen without uniting therewith and producing combustion; that such combustion would proceed with a rapidity dependent on the amount of surface of carbon exposed; and, lastly, that the temperature which the metal would acquire would be also dependent on the rapidity with which the oxygen and carbon were made to combine, and consequently that it was only necessary to bring the oxygen and carbon together in such a manner that a vast surface should be exposed to their mutual action, in order to produce a temperature hitherto unattainable in our largest furnaces. With a view of testing practically this theory, he has constructed a cylindrical vessel of three feet in diameter and five feet in height, somewhat like an ordinary cupola furnace, the interior of which is lined with fire bricks, and at about two inches from the bottom of it he inserted five tuyère pipes, the nozzles of which are formed of well-burnt fireclay, the orifice of each tuyère being about three-eighths of an inch in diameter. At one side of the vessel, about half-way up from the bottom, there is a hole made for running in the crude metal, and on the opposite side there is a tap-hole stopped with loam, by which the iron is run out at the end of the process. A vessel is placed so near to the discharge hole of the blast furnace as to allow the iron to flow along a gutter into it, and a small blast cylinder is used capable of compressing air to about 8lb. or 10lb. to the square inch. A communication having been made between it and the tuyères, the converting vessel is in a condition to commence work. The blast being turned on, and the fluid iron run into the vessel, a rapid boiling up of the metal is heard going on within the vessel, the metal being tossed violently about and dashed from side to side, shaking the vessel, by the force with which it moves, from the throat of the converting vessel. This continues for about fifteen or twenty minutes, during which the oxygen in the atmospheric air combines with the carbon contained in the iron, producing carbonic-acid gas, and at the same time evolving a

powerful heat. The rapid union of carbon and oxygen adds still further to the temperature of the metal, while the diminished quantity of carbon present allows a part of the oxygen to combine with the iron, which undergoes combustion and is converted into an oxide. At the excessive temperature that the metal has now acquired, the oxide, as soon as formed, undergoes fusion, and forms a powerful solvent of those earthy bases that are associated with the iron. The violent ebullition going on mixes most intimately the scoria and metal, every part of which is thus brought in contact with the fluid oxide, which washes and cleanses the metal most thoroughly from the silica and other earthy bases that are combined with the crude iron, while the sulphur and other volatile matters which cling so tenaciously to iron at ordinary temperatures are driven off, the sulphur combining with the oxygen and forming sulphurous acid gas.

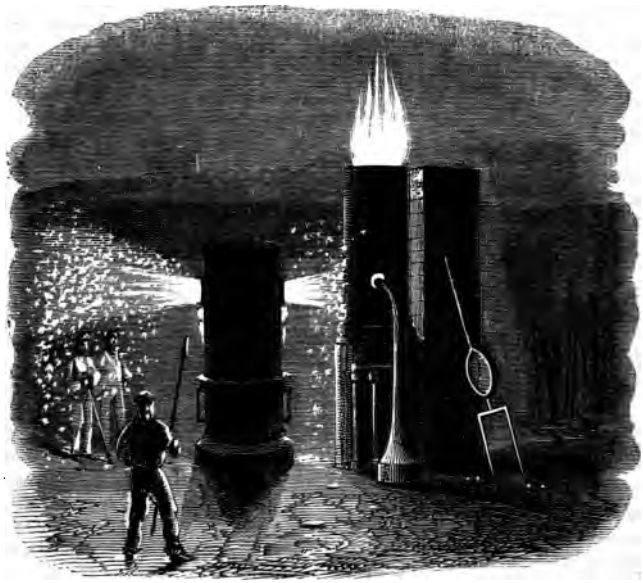


Fig. 206. Mr. Bessemer's Experiments at Baxter House.

"In conducting the demonstration of Bessemer's process, 6 cwt. 3qr. 18lb. of molten iron from a furnace were poured into the fire-brick vessel already described at twelve minutes past one o'clock, the blast having been applied at a pressure of about 8lb. per square inch, and continued until twenty-seven minutes past one. The mass of metal

began to boil up, and the cinders and other impurities were extruded from the top of the vessel by two apertures provided for the purpose. Showers of brilliant sparks were thrown off during this process, which lasted several minutes; and as the object was to produce a mass of cast steel, rather than continue the process to the extent necessary for making pure iron free from carbon, the vessel was tapped at thirty-six minutes past one o'clock, and the contents drawn off. Small specimen ingots being first taken, the general mass was run into an ingeniously contrived mould concealed in the floor in front of the apparatus, and, after remaining there a few minutes, cooling down, it was raised out of the mould in a red-hot state by an hydraulic ram, and placed upon a weighing machine. The ingot thus produced, with the two specimen ingots, weighed 6 cwt. Without the aid of fuel this mass of material was converted in twenty-four minutes from crude cast iron as it comes from the blast furnace into steel of fine quality.

"The experiment was unanimously pronounced by the company to be perfectly satisfactory. It is a peculiar and important feature in the process that by continuing the boiling a few minutes longer the whole of the carbon still remaining in the mass of metal, and which gives to it the character known as steel, would have been burnt off, and a pure spongy mass of crystalline iron would have been the result.

"Mr. Bessemer states that hitherto the finest qualities of iron have always been imported from Sweden and Russia, and these are now sold in this country at from 20*l.* to 30*l.* a ton; but by the new process iron can be manufactured of equal quality at a cost of 2*l.* per ton less than the present cost of common English iron. If this statement be borne out by experience of his invention, we shall no longer be dependent on the foreign market for the production of iron of the finest quality. He also speaks with something like enthusiasm of the extent to which what he calls semi-steel, of a quality between malleable iron and steel in ordinary use, as manufactured under his patent, may be expected to supersede in time the use of malleable iron for railway plates and many other purposes to which the latter is not altogether adapted; and he as confidently asserts that the process of forging and welding, which, under the existing system, is necessary whenever a piece of iron-work of a larger size than from 80lb. to 100lb. is required to be constructed, will be dispensed with. He looks, also, to the universal use of his discovery, seeing that atmospheric air is the prime element used in producing the desired result; it is not, therefore, dependent upon any local circumstances."—*Times.*

Such were the favourable anticipations formed by some practical and scientific men of Bessemer's process, and it is perhaps to be regretted that the invention was brought out too soon; a delay of one or two years would have indicated the difficulties of the process, although it must be remembered that the cost of experiments with iron on anything like a large scale is enormous, and therefore the patentee had only one of two courses open; either to keep what he had discovered a secret, and therefore useless to mankind, or boldly to make his invention public:

the latter alternative was taken, and the theory advanced at the British Association, Cheltenham, in August, 1856; and the experiments in London demonstrated first, that crude pig iron could be wholly decarbonized, while still retaining the fluid state; secondly, that by the injection of atmospheric air into the fluid metal, the combustion thereby produced would, *in the absence of fuel*, raise the temperature of the metal to a degree never before attained in the metallurgical operation; and, thirdly, that the iron so decarbonized, without the employment of fuel, would retain its fluidity long enough to enable it to be cast into ingots capable of extension under the hammer or the rolls.

Pure iron has a specific gravity that is variously stated to be between 7·7 and 7·843 and 7·9. Iron which is not chemically pure, but is still capable of being employed for useful purposes, presents various fractional differences in the important property of specific gravity, as may be observed in the following table:—

	Specific gravity.
No. 1. Black cast iron	6·901 to 6·836
„ 2. Mottled cast iron . . .	7·068
„ 3. White cast iron	7·684
„ 4. Grey cast iron	6·79 to 7·05
„ 5. Hammered bar iron . . .	7·9

Iron may be brought to a high polish and brilliancy, but it presents, under ordinary circumstances, a greyish colour. The hardness of this metal constitutes one of its most valuable properties, and when united with carbon, and possibly nitrogen, it furnishes that most valuable modification of iron called steel, of which more will be said hereafter. Iron is not only very malleable, so that iron books with leaves as thin as paper have been made of it, but it is also astonishingly ductile, and may be drawn into wire as thin as hair. The most useful quality of iron is its superior tenacity or power of resisting a strain; no other metal is equal to it in that respect; hence the value of iron in the manufacture of wire, standing rigging, traction ropes, cables, anchors, and warlike implements, such as cannon and mortars. When iron is drawn out into wire, its strength is said to be 1½ times greater than that of hammered iron, and its enormous tenacity may be appreciated by Rennie's experiments, who proved that an iron wire 0·078 of an inch in diameter, is capable of supporting 449·34 lbs. avoirdupois. The question of bursting and breaking cylindrical or other shaped vessels of iron, such as guns and boilers, has received an impartial elucidation from the experiments of Nairn, who has ascertained that iron begins to change its shape and elongate, when subject to a force equal to 66 per cent. of the power capable of bursting it. The limit of the strength of iron seems to have been reached in Mallet's mammoth 36-inch mortar, which might be called Lord Palmerston's Pacificator. The experiments with this terrific piece of ordnance (shown in frontispiece) have not as yet been successful, partly because it does not project the shell so far as an ordinary 13-inch mortar, and secondly, because the rings of iron or portions of the

strengthening system have given way after one or two discharges; but of its power there can be no doubt, when it is remembered that the shell weighs about twenty-five hundredweight, or rather more than one ton and a quarter. The momentum of such a falling mass must be enormous, and no existing fortifications could withstand for any number of hours the steady application of these shells.

Many years ago the late Professor Barlow ascertained that there is a point beyond which any increase of thickness in a gun or mortar gives no increase of strength. In his treatise on the "Strength of Materials" (1837) he states, speaking of hydrostatic presses,—

"It would at first sight appear that the strength of a cylinder exposed to an internal pressure must be proportioned to its thickness; but practically this is not the case, it being found necessary to increase the thickness in a much higher proportion than in that of the strain."

He then enters into an investigation of the subject, and deduces the following formula:—

$$x = \frac{pr}{c - p};$$

in which x = required thickness of cylinder;
p = internal pressure per square inch;
r = internal radius of cylinder;
c = direct cohesive power of the material of which the cylinder is made;

and he points attention to the fact that "it is obvious from this expression that no thickness will be sufficient to resist an internal pressure which exceeds (per square inch) the cohesive power of a square inch rod of the metal—a result which at first sight appears to be paradoxical; but it will be observed that with such a pressure the interior surface will be fractured before the other parts of the metal are brought into action."

We cannot, then, be surprised, when we read of the partial failure of Mallet's mortar, if we recollect Barlow's law, and also that the initial force of gunpowder, according to Hutton, amounts to two thousand atmospheres, or about thirteen tons pressure per square inch. Even failures are instructive, and, therefore, one of the accounts from the *Times* of the trial of Mallet's mortar is inserted here.

"Another trial of the 36-inch mortar was made in Woolwich Marsh. The experiments commenced at 11 o'clock and terminated at 1.30, with a charge of 50 lbs. of powder, &c., which obtained a range, as on the former occasions, of about 340 yards to each 10 lbs. of powder. A minute examination of the wedges, keys, rings, &c., having been made and pronounced 'all right,' a second charge of 60 lbs. of powder, &c., was introduced. The second round, like the first, was highly successful, the range in this instance exceeding 2000 yards, the shell alighting beyond the butt, in a ditch which separates the marsh from the adjoining property, and creating a tremendous eruption of water, black earth, &c.

According to the prescribed arrangement of adding 10 lbs. of powder to each successive charge, the third round contained 70 lbs., and although the monster gun had stood the first two rounds well, an additional degree of caution was observed by every one present to stand clear of its proximity the instant the match was ignited. The effect of the third round was less successful, as one of the steel cotters broke asunder, and was rendered useless; but as the former experiments had shown the necessity of being provided against a similar casualty, the broken key was replaced, with some slight delay, by a second, wrought of malleable cast iron, supposed to be more durable. The mortar was then reloaded with an 80-lb. charge, and fired with apparent success, the shell again mounting high in the air and taking a flight over 2758 yards, considerably exceeding a mile and a half. The elevation of the mortar was frequently varied, and was ultimately reduced from 48° 30′ to 45°. At this stage of the proceedings it was found impossible to carry on the experiments, as one of the main stays intended to secure the various segments constituting the barrel of the mortar was broken, and one of the principal wedges or cotters, a foot and a half in length, had escaped. The bugles were then sounded, and Lieutenant Walton and the detachment of mounted orderlies and sentries under his command in charge of the range were called in and marched off the ground, and a committee was formed to consult on the expediency and practicability of a continuation of the trial on some future occasion."—*July* 26.

The whole subject of iron is completely of a practical nature, and the information respecting it is so entirely derived from gentlemen who have made this metal their study, that we feel no hesitation in giving here some of the results of the experience of Mr. Richard Solly, of the Leabrook Iron Works, Staffordshire, and of Sheffield. That gentleman remarks that, "although bar iron is commonly divided, by persons unacquainted with its varieties, into two great classes, namely, good iron and bad iron, yet these terms can only be correctly interpreted to mean that a certain iron is suitable or unsuitable for the purpose to which it is applied, for *I am not aware that there is any iron manufactured to be equally suitable for all purposes, nor that there is any so worthless as to be suitable for none.* Some iron may be tough and able to bear great longitudinal strain; such iron is peculiarly fit for chains and chain cables, but *unless* it will weld easily, without requiring such a heat as to injure the tenacity, the links will be liable to break where the welding exists. Other iron may be strong to resist impact, or sharp blows, and stiff—such would make good axletrees: but unless it will turn well, free from asperities and black specks, termed greys, it is not approved. These greys are, in reality, very minute cavities; their perfect absence it is very difficult to attain; when attained, the iron is termed perfectly clear, and fetches a high price. If hard, it will be in request for all articles where a high polish combined with stiffness and strength is required; if soft, for objects requiring tenacity."

Iron, soft and extremely tenacious, by which Mr. Solly means that which will bear much bending backwards and forwards, and a great

strain, without breaking, is also much esteemed for peculiar purposes, such as for the harpoons used in the capture of whales.

Independent of the quality of the iron, after it has been fabricated into the article to be used, it is highly important that it should bear the fabrication into such article with as little liability as possible to be spoiled in the process. A smith will say that such and such iron is *cold-short* or *red-short*, or that it is *unsound*, or that it will not *weld*, or that it will not *punch*, or that it is *full of dirt*, or that, if drawn to a point, it becomes *brittle*. Mr. Solly explains these defects still further: "When a smith puts a piece of bar iron into his smithy fire, he frequently heats it to a white heat, and then begins fashioning the article he is making; as he continues hammering, punching, and bending the iron, it assumes by degrees a yellow, and then a red heat. If the iron be *red-short*, the moment it turns red, if the smith attempt to punch or bend it, the iron cracks, and his work is spoiled. Therefore, in working *red-short* iron, he is obliged to watch the colour carefully and to suspend his work before it turns red, and to put it in the fire to re-heat it. This occasions a loss of time and greater consumption of fuel, and consequently increases the expense of manufacture. The usual mode of trying whether iron be *red-short* is by what is called the ram's head. If this can be done at one heat, that is, without replacing the bar in the fire, it is concluded that it is not *red-short*. *Cold-short* iron usually works well at all heats, and is not liable to crack when under the smith's operations; but when cold it will not bend far without snapping short with a granular appearance, the grain, or crystal, being much larger than in some of the best descriptions of iron, which *may* be granular, but the grains are fine and the colour silvery. Good common irons, and those of best quality for any but special purposes, when nicked on one side and broken by the succesive blows of a hammer, draw out and exhibit a fibrous texture similar to that of an ash stick when broken. Iron for turning purposes is mostly made from scrap, in order to get it as clean as possible, and at the same time free from the seams common in piled iron. The softest and almost the cleanest iron for turning for cotton and other machinery is made from wrought iron *swarf* (or turnings). Sometimes the swarf is worked by itself, but commonly a ball is made of good swarf, and while hot, fine swarf is thrown into the furnace, and the ball is rolled about so that the swarf adheres to it, and it is then taken to the hammer. Piston rods, and other important parts of machinery, are made from faggots of iron bars drawn under a swage hammer, and frequently are twisted, in order to prevent the fibres and seams of the iron from running in the direction of its length, and also to make it more regular in its wear."

In a paper read by Mr. Solly before the British Association, "On Molecular Changes in the Constitution of Wrought Iron," that gentleman was the first to point out that "an extraordinary change is produced in iron by long-continued vibrations, or shocks, or blows of a hammer. It appears to take place more readily in scrap iron than in other kinds, and especially if there are many fillets, or collars, or other *inequalities*, these appearing to destroy the uniformity of the vibrations,

and so assist in inducing a re-arrangement of the molecules. If a shaft or bar be swaged, *i.e.*, gently hammered from a yellow heat until it becomes lukewarm, or turned at the end, either larger or smaller than the other part of the bar, and it be struck at the opposite end with a hammer, the probability is that the former part will fly off after a very few blows have been struck, unless it be held in the hand, or unless the increase or decrease be very gradual. By plunging iron when red-hot frequently into water, the fibres will also lose their form and become quite crystalline, and as brittle as cast-iron. If two pieces of wrought iron work together without lubrication, a kind of union takes place between some of the particles, and the surfaces of the two pieces of iron are torn and galled in a surprising manner. This is termed by mechanics 'seizing,' and is a source of great annoyance to them, as it will sometimes happen while fitting portions of machinery together."

Mr. Samuel Poole states that he has seen a cross-head seized on the end of a piston-rod, so that it was utterly impossible to move it, except by an hydraulic press, or some other powerful means. This fact reminds us of the result that may be obtained by bringing two pieces of ice together whilst submerged in water at a temperature of 32° Fah., the two surfaces immediately adhere and freeze together, called by Dr. Faraday (who has investigated the subject with his usual penetration) regelation. From these experiments, coupled with the remarkable cohesion that takes place sometimes between surfaces of plate-glass, Mr. E. W. Brayley has endeavoured to deduce a general law or the universality of a principle analogous to regelation.

Mr. Solly again observes that "it is remarkable that most *red-short* irons are tough when cold. This is the peculiar property of the Welsh iron in general, but there are some both red-short and cold-short. The best South Staffordshire irons are neither cold-short nor red-short. The defect of red-shortness is generally attributed to the presence of sulphur; cold-shortness, to phosphorus; and difficulty in welding, to arsenic. I have some reason to believe that the addition of flue cinder in the puddling furnace tends to counteract red-shortness. With respect to other of the defects to which I have alluded, we can explain some by the process of manufacture; some we can only guess at; and of the causes of some we are quite ignorant. Two conclusions alone appear to be undisputed, namely, that extremely small quantities of extraneous substances in chemical combination with iron produce most striking alterations in its quality, although such quantities of extraneous substances may be so minute as almost to elude the analysis of the scientific chemist; also, that many of the qualities of iron depend on the particular arrangement of its molecular particles, which may be influenced and altered by merely mechanical operations."

Mr. Solly then proceeds to define other peculiarities and properties belonging to iron, called *body, clearness, soundness, toughness, hardness,* and *softness.*

Body is the property that iron possesses of bearing the considerable and repeated action of the fire without becoming brittle.

Clearness is the absence of greys or small cavities in the iron.
Soundness is freedom from a coating of protoxide of iron, which is an obstacle to perfect welding.
Toughness depends on the molecular arrangement of the particles. Sulphur is said to contribute to the fibrous, and phosphorus to the crystalline state.
Hardness seems to depend on the condition of the carbon, whether combined or uncombined.
Softness appears to be the result of the purity of the iron; that of Biscay being the softest and purest.

Mr. Thorneycroft has likewise shown that compression, or impact upon the end of a bar of iron, will alter its texture from a fibrous to a granular character; and he states that this is well exemplified by two tools used by forgemen. The first is called the "gag," which is a short bar of iron of about two inches diameter, employed for holding up the end of the large helve during the intervals of working; it is subjected to impact endways, whenever the lower end is placed on the anvil, and the other receives a vertical blow from the helve falling about an inch upon it. However fibrous may be the quality of iron used for making the "gag," it soon becomes brittle, and literally falls to pieces as if it were made of cast-iron.

The second instance is that of the tool employed in puddling, one end of which is constantly subject to blows from a small hammer, in order to detach the metal which adheres to the other extremity. After being some time in use, it frequently breaks at a slight blow, exhibiting a perfectly granular fracture. If a bar of fibrous iron be bent down at a short angle, the fibres of one side are compressed, and those of the other

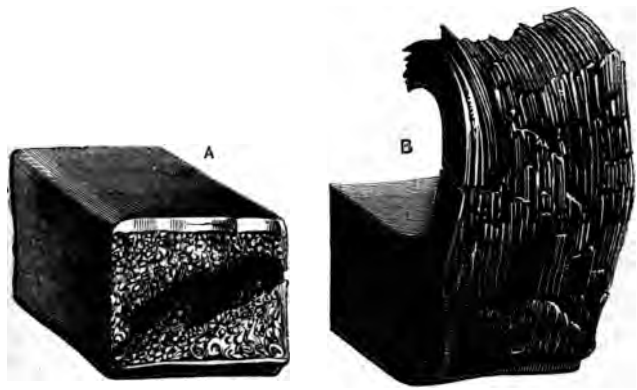


Fig. 207. A. Granular fracture of iron. B. Fibrous fracture of iron.

side elongated, and after being bent back again, the fracture on the compressed side will exhibit a granular appearance, having evidently lost the fibre and been broken off short, as at Fig. 207, A and B.

One of the greatest sources of mischief to the internal molecular structure of a bar of iron is the cold swaging or hammering which is given to the iron in order to give it a nice appearance. Mr. Nasmyth subjected two pieces of cable bolt iron to one hundred and sixty blows between swages, and afterwards annealed one of the pieces for a few hours. The unannealed piece broke with five or six blows of a hammer, showing a crystallized fracture, while the annealed piece was bent double under a great number of blows, and exhibited a fine fibrous texture; thus showing that the fibrous texture could be restored apparently by readjusting the combined or latent heat of the iron. Mr. Gravatt mentions a case at the Thames Tunnel, where the "fleeting bars" used as levers for turning the large screws for forcing forward the shield never lasted longer than three or four weeks, although they were very strong, and were made from the best materials by careful smiths. They were only used occasionally, and then without any concussion, having only the power of eight men exerted upon them; yet they broke constantly, and the fracture exhibited a bright crystallized appearance. It was found at last that, in order to give them duration, they should be left rough, and not hammered much in working.

In wrought-iron guns it might be expected that the repeated concussion arising from the discharge of the gunpowder would gradually bring about a change in the molecular structure of the iron; but this does not appear to be the case, and may be due to the great heat evolved by the combustion of the gunpowder, readjusting the balance of the latent heat of the forged iron, which might otherwise be disturbed, and produce the granular and brittle state. The whole phenomena represent, perhaps, the most curious properties belonging to the metal iron, and deserve still further investigation.

Returning again to the question of the impact or blow that iron is capable of sustaining, it is evident that the quality of cast iron is extremely variable, and consequently the greatest care must be used in selecting the very best iron for the manufacture of cannon; and even with the utmost caution accidents arise similar to that most unfortunate one recorded last August, which occurred with the volunteer artillery at Dover Castle, when a large piece of ordnance suddenly burst and killed several gentlemen. The use of a tougher iron therefore becomes desirable, and the discovery of the wrought-iron gun of Sir William Armstrong seems just to have been made at the right moment, when wars and rumours of wars compel the most peacefully-disposed nations to arise in self-defence. Consequently the British nation hailed with pleasure the account given of the new wrought-iron gun, by the then Mr., and now Sir William Armstrong, in the *Times* of the 3rd of January, 1857, and headed "Experiments in Gunnery." The learned *civilian* engineer says—

"In the latter part of 1854 I submitted to the Duke of Newcastle,

then Minister at War, a proposal for a gun which I anticipated would possess great superiority over the common forms of light artillery, and I undertook, with his Grace's authority, to construct a field-piece in conformity with the plan I had suggested. The gun was accordingly soon afterwards made, and has since, during a period of nearly two years, been the subject of numerous experiments, partly upon the Ordnance firing-ground at Shoeburyness, but principally under my own direction in this neighbourhood.

"I have hitherto avoided publicity in reference to these experiments, but, as matured results of much interest and importance have now been arrived at, and as other names are already before the public in connexion with gun experiments made during the same period, I feel that I may now, without impropriety, give some information on the subject.

"With a view to strength and durability, the gun is composed internally of steel and externally of wrought-iron, applied in a twisted or spiral form, as in a musket or fowling-piece. The bore is nearly two inches in diameter, and is rifled. The projectile is a pointed cylinder six inches and a half long, and its weight is five pounds. It is made of cast iron, coated with lead, and is fired from the gun with a charge of ten ounces of powder; it contains a small cavity in the centre, and may be used either as a shot or a shell. When applied as a shell the cavity is filled with powder, and a detonating fuse is inserted in front, so as to fire the powder in the centre on striking an object. When used as a shot the powder is omitted, and an iron point, which favours penetration, is substituted for the fuse. The gun is constructed to load at the breech, the object being not only to obviate the disadvantages of sponging and loading from the front, but also to allow the projectile to be larger in diameter than would enter at the muzzle, and thus to insure its taking the impress of the grooves and completely filling the bore. The piece weighs 5 cwt., and is mounted upon a carriage which bears a general resemblance to that of an ordinary 6-pounder field-gun, but which embraces a pivot frame and recoil slide. A screw is also applied, not only for elevating and depressing the gun, but also for moving it horizontally, by which means great delicacy of aim is effected. The recoil slide has an upward inclination, which enables the gun, after running back, to recover its position by gravity, and its use is to relieve the pivot-frame and adjusting screws from injurious concussion.

"I shall now give some particulars of the experiments recently made with this gun on the coast of Northumberland, near the village of Whitley, under the official inspection of Colonel Wilmot.

"Fourteen shots were in the first instance fired from a distance of 1500 yards at a timber butt, 5 feet wide and 7½ feet high. Six of these were expended in finding the elevation proper for the distance, but after that was determined, every succeeding shot hit the object without previous graze. The final elevation of the gun was 4 degrees 26 minutes, and the mean lateral distance of the shot marked from a vertical line through the centre of the butt was only 11½ inches.

"Persons who are conversant with artillery practice will be able to

appreciate the accuracy of this firing, but for the information of those who are unacquainted with the subject, I may state that the ordinary 6-pounder field-piece, which in point of weight forms the nearest approach to the present gun, is perfectly useless at a distance of 1500 yards, and is very uncertain even at 1000. It is only, therefore, with heavy artillery that a comparison can be drawn, and it will be sufficient to state that in tabulating the practice made with such ordnance the deflections are invariably recorded in yards, whereas with this rifled gun they can only be properly given in inches.

"With respect to penetration, the following particulars will be regarded as equally remarkable, considering the small weight of the shot and the length of the range. The butt was three feet thick, and was composed of six layers of rock elm bolted together, so as to form a solid block. One shot passed entirely through, another struck near the edge and glanced, and the remaining six penetrated within a few inches of the opposite side.

"Shell firing was next tried at a distance of 1500 yards, the gun being fired at the same elevation and with the same charge as in the previous practice at the butt.

"In this case two targets were erected, one behind the other, so as to appear as one object when viewed from the gun, and a space of thirty feet was left between them. The front target was intended to exhibit the perforations of the shells before bursting, and the back one to show the effect of the fragments resulting from explosion.

"After some preliminary experiments, twenty-two shells were fired at the front target, and of these only one missed the object of aim. The following are the particulars: Seventeen hit the first target direct, and burst behind it, the fragments penetrating the second one; three grazed and burst immediately in front of the first target, and perforated both with the pieces; one hit the bottom of the first target and exploded in the ground, and the remaining one missed entirely and burst on some rocks nearly in line beyond. A strong side wind was blowing at the time, and accounted for the deviation of this single shell.

"Four shells and three shot were then fired at an elevation of six degrees, from a distance of 2000, or, more accurately, 1964 yards. All these struck within the breadth of the target; but the elevation being scarcely sufficient, they all fell a little short, except one shell, which, ranging somewhat further than the others, hit the target and burst as usual.

"The results of this shell firing were as follows: The front target contained 51 holes, and the back one 164, while the ground between and adjacent to the targets exhibited about 70 perforations by fragments of shells, the greater portion of which were afterwards recovered by digging.

"With respect to ranges exceeding 2000 yards, I may state that on previous occasions the gun had been tried up to 3000 yards—a distance which was reached with an elevation of eleven degrees, and the usual charge of ten ounces of powder, or one-eighth the weight of the pro-

jectile. By augmenting the charge the range is increased, but the accuracy is impaired, and I therefore adhere to the ten-ounce charge, which gives ample penetration, as the experiments at the butt will testify. I may also observe that the ranges obtained with this charge bear a favourable comparison with those of the heaviest round-shot guns fired with a much larger proportion of powder.

"It is a curious fact, and one which greatly increases the efficiency of the shells, that, owing to the bursting charge requiring a minute space of time to mature its ignition after the firing of the fuse by impact, the shell is enabled to travel four or five feet after striking an object before disruption takes place. Hence, therefore, it acts as a shot before it bursts as a shell. When it perforates a target the explosion may be seen to take place a few feet beyond, and when it grazes it has time to rise, and may be observed to burst after clearing the ground. If, therefore, it were fired against a ship, it would first penetrate the side in its entirety, and then bursting, traverse the deck in fragments; or if directed against troops, it would pierce the front line as a bullet, and operate like grape shot beyond. The shells explode with equal certainty, whether the first substance struck be hard or soft, and, in fact, they even burst on the surface of water, provided the elevation of the gun be not too great. The bursting charge is very small, but it suffices to break the shell into about thirty pieces, which pursue their forward course without too much dispersion.

"It is impossible to contemplate the results obtained with this gun without being impressed with the important part it is calculated to perform in warfare. Opposed to any ordinary field-piece, it would be like the Minié rifle against the old musket, and no gun could be worked at an embrasure if a fire of shells were directed against it by one of these rifled pieces placed within the distance of a mile. In naval operations, also, guns of this description, but of larger size, might apparently be applied with great effect—more especially as a system of breech-loading, combined with a self-recovering recoil action, would be peculiarly advantageous in firing from portholes. Even light five-pounders sending their shells from great distances through the sides of a ship, and sweeping the decks with fragments of lead and iron, would produce very destructive effects, and a small swift steamer carrying a few such guns might prove a very troublesome opponent to a large ship of war. But if the dimensions of the gun were increased so as to adapt it for shells of 20 lb. or 30 lb., still more terrible injury could be inflicted at greater distances, and the ponderous artillery now used at sea would be of little service when opposed to the accurate and long-range firing of such rifled shell-guns.

"It now only remains to be stated that in the course of the long series of experiments made with this gun it has been fired nearly 1300 times without sustaining any permanent injury, either in the breech-loading arrangement or otherwise. The only parts exposed to wear (and none are seriously so) are separable from the gun, and can with great facility be renewed."

The sequel to this letter is too well known to require comment except in praise of the Government, who have secured this valuable invention and erected great works at Woolwich for the manufacture of the Armstrong guns. Since the use of the wrought-iron gun, Mr. Whitworth, the celebrated engineer, has brought forward his gun, called the Whitworth gun, which bids fair to equal in the results obtainable

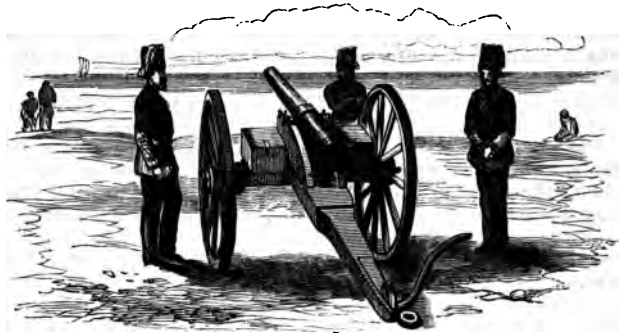


Fig. 208. Whitworth Gun.

from it those already ascertained to belong to the Armstrong weapon. Considering the immense number of fortified places belonging to Great Britain where the old cast guns must all eventually be replaced by rifled cannon, it is not too much to anticipate that the work will be divided between these two great engineers, and that for every "Armstrong" we shall have a "Whitworth" gun. The old caution of "not having too many eggs in one basket" may apply with peculiar aptness to the manufacture of only one kind of ordnance; although, so far as we know at present, the Armstrong gun is as near perfection as a gun can be, and that the first letter written by Sir William Armstrong on his new gun is not an exaggeration is proved by the results lately obtained with a 100-pounder gun of this construction, and headed in the *Times* of August, 1860, as the warlike case of "Armstrong *v.* Martello."

"The Martello tower at Eastbourne, selected as the object to be fired at, was one which the sea was gradually undermining, and the guns employed were a 40-pounder of 31 cwt., an 80-pounder of 63 cwt., and a short 100-pounder, weighing only 53 cwt. The distance was 1032 yards, and the projectiles employed were partly solid shot, and partly percussion shells. The tower was built of very strong brickwork, the thickness of the walls being 7 ft. 3 in. on the land side, and 9 ft. on the side next the sea. It measured 48 ft. in diameter at the base, and was upwards of 30 ft. high. Like all other Martello towers, it was arranged

to carry one heavy gun *en barbette*. The roof or platform bearing this gun consisted of a massive vault of great strength, supported by the walls and by a solid pillar of brickwork occupying the centre of the tower. The chief merit which has been claimed for Martello towers is that, from their circular form, they deflect all shot which strike them in the curve; but the accuracy of rifled guns has rendered this advantage of small importance, while the exposed condition of the gun on the top would render it entirely useless against arms of precision. The experiments commenced by a few rounds of solid shot from the 40-pounder and the 80-pounder, and of blind shells from the 100-pounder, the object being to ascertain the penetration of these various projectiles. The 80-pounder shot was found to pass quite through the wall into the tower, piercing 7 feet 3 inches of brickwork; the others lodged in the wall at the depth of about 5 feet. Live shells were then fired, and with so much effect that after eight or ten rounds from each gun the interior of the tower became exposed to view. The firing was then suspended to enable his Royal Highness the Commander-in-Chief, who was present, to examine the breach, and also to allow of the execution of a photograph. The fire was resumed in the evening, and continued at intervals on the following day. The centre pillar supporting the bomb-proof roof was speedily knocked away, but the structure was so compact that the vault continued to stand, and was only brought down by a succession of shells exploded in the brickwork. Nothing could

Fig. 209. View of the Martello Tower after its Destruction by the Armstrong Guns.

exceed the precision with which these shells were thrown. The broken section of the vault was itself but a small object to hit, but this was done with such unerring certainty that the very spot selected was almost invariably struck. The total number of shot and shell fired against the tower was 170, of which only a small proportion was from the 100-pounder. The ultimate result was that the land side of the tower was completely destroyed, and the interior space filled with the *débris* of the vaulted roof. The opposite side was also injured, but the mound of fallen materials saved it from destruction. We may infer from these valuable experiments that no species of masonry or brickwork penetrable by percussion shells will in future be available in fortification. Nor is it conceivable how wooden ships are to withstand the effects of such projectiles. The 100-pounder gun used on this occasion is probably the most formidable weapon ever yet produced. Its shell, which weighs 100 lbs., contains 8 lbs. of powder, and yet the weight of the gun with which this tremendous projectile is discharged is less than that of the ordinary 32-pounder, the weight of which is 56 cwt."

Experiments with Iron.

First Series.

To obtain chemically pure iron, sesquioxide of iron, prepared by the process described at p. 385, is placed in a hard green glass tube, one end of which is drawn out to a capillary tube, and the other connected by *caoutchouc* (not vulcanized india-rubber, because that substance contains sulphur), with an apparatus for generating and making pure hydrogen free from phosphorus, hydrocarbon vapour, arsenic, antimony, or sulphur. The tube containing the pure sesquioxide of iron is moderately heated, whilst the pure hydrogen passes through it, and the latter, combining with the oxygen of the sesquioxide of iron, produces water, which is driven out of the tube by the heat, and the iron remains in the metallic state, but in a curious pyrophoric condition, so that when shaken into the air it takes fire like pyrophoric lead, copper, or antimony, and the property of burning spontaneously when brought in contact with the air is said to be much increased by the addition of a little alumina to the sesquioxide of iron. Another mode of obtaining pure iron is to melt some of the finest Biscay iron from Spain in its own scales, with some pure green glass free from lead, in a porcelain crucible placed inside a Hessian crucible, and exposed to the *most intense* heat of a wind furnace.

If anything will try the heating power of a wind furnace, it is melting pure iron, and the author recollects the *gusto* with which his old teacher, Mr. John Thomas Cooper, used to relate the story of Dr. Wollaston asking him if he had a wind furnace? On replying in the affirmative, the doctor, intent upon a little quiet fun, put into his hands some horse-shoe nails, and asked him to be good enough to melt them. Mr. Cooper used to say, "By Jove! I melted them, but it was a tough job; and when

I put the melted nails into Wollaston's hand, all he said was, 'Oh!'" The Biscay iron contains only a little carbon, and this acted upon by the oxygen in the iron scales is burnt away, whilst the excess dissolves in the glass, forming a silicate of iron, and the metal itself is found at the bottom of the crucible. The erection of a wind furnace and chimney being somewhat expensive, it is extremely useful to know that for all temperatures up to that of the melting point of *cast* iron, a most useful patent blast gas furnace has been invented by the eminent philosophical instrument maker, Mr. John Joseph Griffin, of Bunhill-row, Finsbury.

"This furnace is intended for the fusion of refractory metals, and for other purposes which demand a high temperature, producible with readiness, and under complete control. The fuel is common coal gas, taken at the ordinary pressure, and supplied with a blast of atmospheric air by means of a blowing machine. The apparatus consists of an iron gas burner, and a clay furnace packed with small flints. The gas burner is a cylindrical iron reservoir, constructed as shown in section in Fig. 210, which is drawn on a scale of one-third the full size. It contains two chambers, which are not in communication with one another. Into the upper chamber gas is allowed to pass by the tube marked gas. Into the lower chamber air is forced by the tube marked air. The upper part of the burner is an inch thick in the metal. Through this solid roof holes are bored for the escape of the gas. The air passes from the lower chamber through a series of metal tubes placed in the centre of the gas holes, and continued to the surface of the burner, so that the gas and air do not mix until both have left the gas burner, and then a current of air blows through the middle of each jet of gas. The gas and air pipes generally used are both half an inch in the bore, and about ten inches long; the gas has usually had a pressure of half an inch of water, and the blast of air about ten times that pressure. The quantity of gas used in an hour is about one hundred cubic feet, when the gas burner contains sixteen jets. The jet of blue flame produced by such a burner, when the gas is lighted and the blast of air is set on, is about two inches in diameter and three inches in length. It can be directed into the furnace either at the top or the bottom. Fig. 211 represents a section of a gas furnace heated by the top; *a*, is a gas burner, similar to Fig. 210; *b*, is a support for the burner, to be used as represented in Fig. 212; *d*, and *d'*, are two plates of fire-clay, bored to fit the nozzle of the gas burner; *e*, *e*, are two cylinders of fire-clay; *c*, is an iron support for the furnace. Upon the base, *d*, is placed a perforated cylinder of fire-clay, and upon that as many discs of fire-clay as bring the crucible that is to

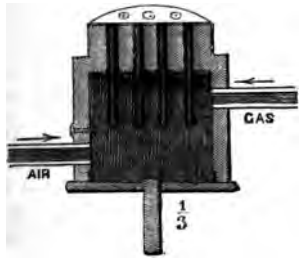


Fig. 210. The Gas Burner.

be heated up to the top of the furnace. A perforated cylinder of plumbago is placed round the crucible, and the space between the middle

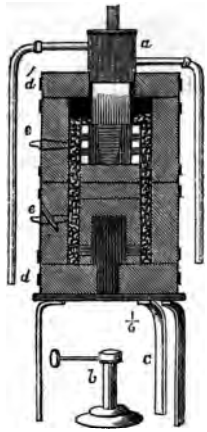


Fig. 211. Section of Gas Furnace with Gas Jet at the Top.

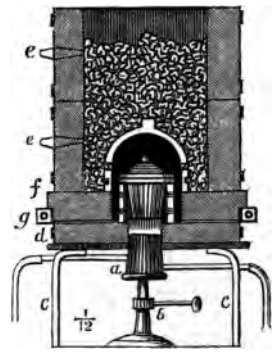


Fig. 212. Gas Furnace with Gas Jet at the Bottom.

pile and the walls of the furnace is filled with flat stones, of about half an inch diameter. The cover, *d'*, is then to be put on, the gas is to be lighted, the blower to be put into action, and the flame to be directed down into the furnace. The whole force of the blue flame then acts directly upon the crucible. The products of the combustion of the gas, and the nitrogen and surplus air, escape at the bottom of the furnace, leaving most of their heat with the pebbles, crucible, &c. Fig. 212 represents a gas furnace arranged for being heated at the bottom. The parts marked *a*, *b*, *c*, *d*, *e*, *e*, have been already described; but the piece marked *f*, *g*, *g*, and represented separately by Fig. 213, is a false bottom,

Fig. 213. False Bottom for Gas Furnace.

consisting of a fire-clay plate, mounted with a pair of iron handles. The crucible to be heated is flanged at the mouth, Fig. 214, and rests by the flange on a perforated cylinder of plumbago, Fig. 215. This cylinder rests on the fire-clay plate, *d*, Fig. 212. Upon the false bottom, *f*, is placed

a perforated dome or hemisphere of fire-clay or plumbago, and above the dome the furnace is filled with small flints. The flame is put in at the

Fig. 214. Crucible to be heated.

Fig. 215. The Perforated Cylinder of Plumbago.

bottom. When the crucible is to be examined, the whole upper part of the furnace can be lifted by means of the handles, *g*, *g* (Fig. 213), and, if necessary, can be easily replaced. The heat produced by this furnace is sufficient for the fusion of silver, gold, copper, cast iron, wrought iron, nickel, and cobalt. One pound of copper can be melted in ten minutes, three pounds in fifteen minutes, ten pounds in an hour. Cast iron melts with nearly equal facility."

The author has witnessed the most satisfactory results obtained with this patent gas blast furnace, and cannot too highly recommend it to practical chemists and amateurs. If the crucible containing the melted cast iron is removed and poured from a moderate height on to a level iron tray about three feet in diameter, a magnificent series of sparks are thrown upwards as the iron burns in contact with the oxygen of the air.

Second Series.

The equivalent of iron is 28, and it combines with oxygen in several proportions, as follows:—

Protoxide of iron	FeO
Sesquioxide of iron	Fe_2O_3
Ferric acid	FeO_3
The mixture of the protoxide and sesquioxide called magnetic oxide of iron	Fe_3O_4

If a solution of pure sulphate of iron free from dissolved air is placed under a jar filled with hydrogen gas, and provided with a brass cap and sliding rod to which is attached a test tube containing some strong solution of potash, also free from dissolved air, no action of course takes place until the potash is thrust into the solution of iron, when a white precipitate of the hydrated protoxide of iron (FeO,HO) is obtained, which quickly changes to the green hydrated magnetic oxide, and gradually to the red or sesquioxide of iron by exposure in another jar containing oxygen gas or air. If the liquid containing the hydrated oxide is boiled, it changes black, and is converted into the state of anhydrous protoxide of iron (FeO), which, however, is always more or less altered by the oxygen of the water, so that it is impos-

sible to obtain it absolutely pure. It is this oxide which is the base of that important salt called green vitriol, or sulphate of iron, used so extensively by dyers and calico printers, and likewise in the manufacture of ink.

The sesquioxide of iron (Fe_2O_3) is always the condition in which iron is estimated by analytical chemists, and is produced by boiling any of the proto-salts with dilute nitric acid until no more orange-red fumes escape. Thus, supposing iron is dissolved in hydrochloric acid, and ammonia added in excess, the protoxide is certainly precipitated, but very imperfectly, because it is soluble in ammonia. If, however, the solution of chloride of iron is first boiled with an excess of nitric acid, and a slight excess of ammonia added, a very bulky red precipitate is formed, which is the hydrated sesquioxide of iron. This precipitate must then be collected, washed, dried, and ignited, and is the sesquioxide of iron (Fe_2O_3).

It has been shown by Mr. John Spiller, assistant in the chemical establishment of the War Department, Woolwich,* that the sesquioxide of iron, in common with many other bases, is disguised by the presence of citric acid. "A solution of the sesquichloride of iron is not precipitated by ferrocyanide of potassium, benzoate, or succinate of ammonia; nor is the coloured reaction produced with acetate of potassa, ferricyanide, or sulphocyanide of potassium. The reaction between sesquichloride of iron and ferrocyanide of potassium is curiously modified. On mixing these two solutions in the presence of an alkaline citrate, a yellow solution is formed, which becomes deep-blue in colour on largely increasing the amount of ferrocyanide of potassium; no precipitate of Prussian blue is produced until hydrochloric acid in excess is added. Neither potassa nor ammonia will precipitate protoxide of iron in the presence of citric acid. The alkaline product so obtained, gives with sulphide of ammonium, if dilute, a dark olive-green solution; but if more concentrated, an immediate precipitate, with a supernatant liquid of that colour. The sulphide of iron comes down, however, on boiling, or on standing for a sufficient length of time in the cold. The protophosphate of iron is held in solution, and the reaction between ferrocyanide of potassium and a protoxide of iron is entirely masked."

Ferric acid has never been isolated, and is only known in combination with potash, soda, lime, baryta, &c. The magnetic oxide of iron is interesting, not only because it occurs in nature as the loadstone, and sometimes most perfectly crystallized in octohedra, but also on account of the numerous simple processes by which it can be made. Thus, if a bundle of very thin iron wire is attached to a bit of lighted taper and plunged into a jar of oxygen gas, a most brilliant combustion of the iron takes place, and if the gas jar is standing in an earthen dish, the ignited magnetic oxide of iron falls through the water and melts itself into the glaze; but if the jar is placed in a stout metal dish, the surface of which is blackleaded, then the globules of black magnetic

* Quarterly Journal of the Chemical Society, July, 1857.

oxide of iron may be removed with greater facility, at the same time exhibiting most perfectly that peculiar condition of heated matter by which water is repelled, as it were, from the surface, and does not come in contact with it until the temperature has sunk below the point that will produce the spheroidal state.

During the combustion of steel or iron in oxygen a quantity of the sesquioxide of iron is also produced in such a very fine state of division, that it appears for the time to be quite vaporous, and does, indeed, condense on the sides of the gas jar as a red powder. If steam is passed over fine iron wire heated to redness in a gun-barrel, the magnetic oxide is produced, which crystallizes in minute octohedra.

The hydrated magnetic oxide is not difficult to make, and is somewhat amusing on account of its following the course of a powerful magnet, if the latter be held against the sides of the bottle containing it. Divide a solution of sulphate of iron into three parts, boil two of them with nitric acid to convert the iron into the sesquioxide, let it cool, and then add the third, and pour the whole into a strong solution of ammonia, taking care that the latter is in excess, and that the whole is well stirred. The order of the process must be strictly attended to, or it will fail to produce the true hydrated magnetic oxide.

Fig. 216. Magnet drawing up the Magnetic Oxide of Iron (contained in Water) at the Side of the Bottle.

It is the oxide of iron which imparts the colour to bricks, and also to many jewels and precious stones. The sapphire, the garnet, the topaz, the amethyst, all contain oxide of iron, and the blue of the lapis-lazuli has been imitated with great success by combining silica, oxide of iron, &c., in a peculiar manner, as by the process lately conducted by Messrs. Beard at the Wharf-road, City-basin. Both iron and steel are oxidized in the most brilliant manner by mixing them in the divided state of filings with gunpowder, sulphur, and charcoal. The firework is called a gerb, and is termed iron or steel, according to the nature of the filings used. The following proportions give fair results :—

	Meal gunpowder.	Nitre.	Charcoal.	Sulphur.	Cast-iron filings.	Steel filings.
Iron gerb .	16	8	3	3	10	—
Steel gerb .	16	—	—	—	—	16

These materials are mixed when required, and rammed into cases, because the gerbs become useless if kept any length of time, in consequence of the sulphur combining with the iron. The steel filings produce long needle-shaped sparks, and the iron filings afford stars or rosettes, that burst and break in the most beautiful manner as they fall to the ground.

The rapidity with which steel filings oxidize is well shown by making a large flame with alcohol in a flat stout tin dish, and throwing into it a mixture of gunpowder and steel filings. The latter burn with great rapidity, whilst the former drops through the flame in large quantities unburnt; and when the flame is extinguished, the alcohol poured off, and the gunpowder dried, it may be fired on the application of a lighted taper, proving that the flame did not ignite the powder as it passed through the alcohol flame.

Third Series.

Chlorine, iodine, bromine, and fluorine unite with iron and form salts, which are chiefly interesting to the scientific chemist and the medical practitioner.

The combinations of sulphur with iron deserve notice in this work, because the sulphide (FeS) is the chief source of sulphuretted hydrogen, so frequently required in the chemist's laboratory. The sulphide of iron is made by placing some common iron tenpenny nails in a crucible provided with a cover, and heating them to a bright red heat; bits of roll sulphur are then thrown in, and the lid of the crucible put on after each portion of the sulphur is added. If the heat of the furnace is kept up properly, and the sulphur added till the iron nails are fused and nearly melted away, the sulphide of iron is formed, which may be allowed to cool in the crucible, or may be poured out into a proper conical mould, and when cold broken up and put into a dry, corked bottle. The sulphide of iron may also be prepared by heating the end of a bar of iron in Griffin's gas furnace, and then if a roll of sulphur is brought in contact with the white hot iron, an intense action takes place, and the bar of iron melts down in great drops of sulphide, which exhibit, as they fall into water, the same curious repellent power already observed with other metallic bodies, and especially with heated silver, as shown by M. Boutigny.

Sulphuretted hydrogen is readily made by pouring dilute sulphuric acid upon sulphide of iron; but as the escape of this gas into the air of the laboratory is very disagreeable, not to say hurtful, to person and property, it is better to fit up an apparatus (like that recommended by Fresenius) when it is required to be constantly used. This arrangement consists of an upper and a lower vessel made of lead, soldered with pure lead. The sulphide of iron is placed on a shelf in the lower vessel, and dilute sulphuric acid in the top one, and by the proper disposition of the

pipes the gas is always stored ready for use, whilst if any escapes it is made to pass through ammonia, and being absorbed, forms that most useful test called sulphide of ammonium.

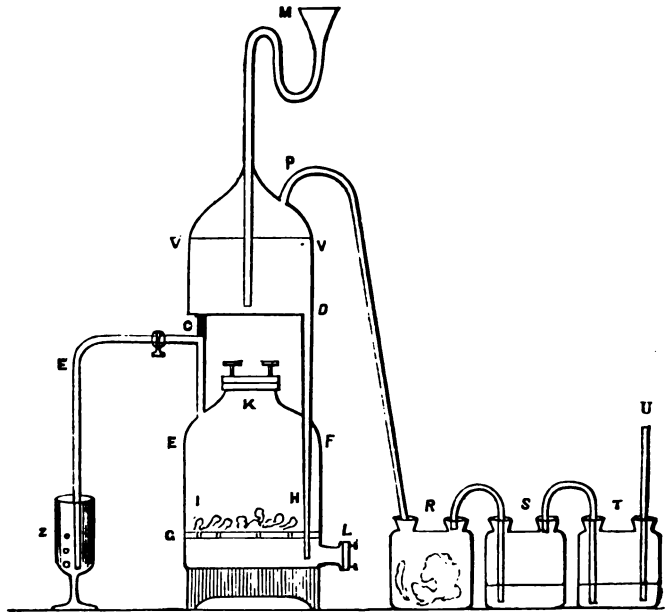


Fig. 217. I. Perforated shelf of lead, on which the sulphide of iron is placed through the aperture K, closed with well-greased leather. L. Opening for running off the sulphate of iron when required. M. Filling tube, down which the dilute sulphuric acid is poured. D H. Tube that conveys acid to I. C H. Tube from H F G, the generating vessel which conveys the sulphuretted hydrogen to the glass Z, and can be turned off by a cock at C. P. Tube to convey waste gas to the three Wolfe's bottles, R, S, T. R contains cotton-wool; S, ammonia; T, ammonia. U is a safety-tube. When the sulphide of iron is placed on the shelf I, acid is poured into the top vessel V V, through M; and directly the cock C is turned, the acid makes its way to the sulphide of iron on the shelf I, in the lower vessel H F G. As all the tubes are made of small diameter, the gas generated escapes only in a limited proportion by the tube C H, and its pressure stops the descent of more acid from V V. Directly the cock C is turned, the gas drives the acid back into V V, and then the little gas that continues to escape from the acid which wets the sulphide of iron bubbles up through the pipe D H, and escapes at P, from which it passes to the Wolfe's bottles, R, S, T, containing the ammonia. As before, directly the cock C is turned, sulphuretted hydrogen escapes, until, in the course of some weeks, the sulphide of iron has been entirely decomposed.

The mineral called iron pyrites is a bisulphide of iron (FeS_2), and under the name of marcasite was much used formerly as an ornament, being set like steel stud ornaments of the present time, in brooches, bracelets, &c.

Fourth Series.

The combination of carbon with iron is too important to be passed by in silence, because it is the peculiar union or mixture of these two elements which produces that valuable body called steel.

The only approach to an atomic combination of iron and carbon is in the formula of Fe_4C, obtained by heating iron in contact with powdered charcoal, but that proportion is not maintained when the steel is worked up for use; perhaps the presence of the definite compound of Fe_4C, diffused or alloyed through the mass of metallic iron, may produce those remarkable effects which confer upon iron the properties of extreme hardness and elasticity, with intermediate gradations. In Bessemer's process it is shown, that by arresting the combustion of the carbon (always present in the cast iron) at a particular point, steel is produced of fair quality and of remarkable cheapness, because no intermediate processes are required. The cast iron, in fact, may be taken direct from the blast furnace to Bessemer's apparatus, and converted at once into steel. If (as Mr. Binks has shown) nitrogen appears to fulfil some office in the conversion of iron into steel, then Bessemer's process must again be the right principle, because in the act of driving air through the molten iron large quantities of nitrogen are thus brought in contact with the heated metal.

Mr. Binks has shown that the contact of red-hot charcoal with iron, in the absence of nitrogen, will not produce steel, which is usually made by a process called cementation. Bars of iron are laid in large fire-clay boxes filled with powdered charcoal, which are then heated red hot and kept in that state for six or eight days, with the partial admission of air, until a sample bar taken from the box exhibits the unequivocal signs of proper cementation by the appearance of numerous blisters on the surface. The steel in this state is called "blistered steel," and its physical character is changed, being full of cavities and inequalities, which must be closed by heating and hammering, or "tilting," and after having undergone this process, it is called "tilted steel."

Shear steel derives its name from the accidental circumstance of tailors' shears being forged from it; it is made by breaking up the bars of "blistered steel" into lengths of about eighteen inches, which are then bound together in bundles containing four lengths, and also a fifth of double length, whose projecting end is used as a handle. A thin steel rod is twisted round them like the binding of a faggot of firewood, and the whole is brought to a welding heat, sprinkled with sand, and placed under the tilt hammer, and after sufficient hammering, the mass is rolled and drawn out into a long rod; table knives, surgical instruments, powerful springs, gun locks, &c., are made of shear steel.

Cast steel is manufactured by breaking up and melting the blistered steel in proper crucibles, with a little bottle glass to protect the surface of the melted metal from oxidation. Some fifteen years ago there used to be a "steel works" at Millbank, where the author has seen all these processes conducted, from the manufacture of the blistered steel to its

conversion into "tilted," shear, and cast steel, but now the locality is covered with the buildings of "Cubittopolis." It was at these works the author saw the alloying of iron with manganese (under the auspices of the spirited proprietor, Mr. Johnson), which was then a patented process, but now the common property of all, because the unfortunate patentee was deprived of his rights by some freak of the patent law.

The presence of manganese in iron converted into steel appears to confer the property of lasting hardness to the edges of cutting instruments, and the author has an excellent pair of razors made twenty years ago with steel containing manganese.

Fig. 218. A Thirty-two Pounder Earth Battery (rear view).

As we have spoken of the Armstrong and Whitworth guns, mention must be made of Mr. Krupp's cast-steel gun, and if this weapon could be made and rifled at a cheaper price, it would probably compete very favourably with those of the English engineers. Although one burst at Woolwich, March 19, 1855, in consequence of certain liberties having been taken with it by endeavouring to fire an expanding shot weighing two hundred and fifty-nine pounds, instead of one of sixty-eight, for which it was intended, the "Krupp cast steel" gun enjoys a high reputation, proved by the fact that since the bursting of this piece Mr.

Krupp has manufactured guns and mortars for the arsenals of Prussia, Russia, Wurtemberg, Switzerland, Egypt, and France.

Two 12-pounder howitzers made by Krupp were tried at Vincennes, by firing three thousand rounds with the usual service charges, and did not exhibit in the chamber or box the slightest trace of injury. One of the guns was then subjected to the following severe proofs:—

20	rounds with	6 lbs. 9 oz.	of powder and	2	balls.
10	„	„ „	„	3	„
5	„	13 lbs. 6 oz.	„	6	„

At this point the experiments were wisely stopped, in order to preserve so valuable a piece.

Steel may be distinguished from iron by letting fall a drop of nitric acid on the surface, which produces a greyish black spot, whereas that of iron is red with the same acid.

Steel filings produce a spark, during the act of combustion, which is quite different from that of iron filings.

Steel remains permanently magnetic when properly magnetised, whereas iron receives, but does not retain its magnetic power.

Steel possesses the curious property of assuming various colours and degrees of hardness and elasticity, according to the temperature at which it is heated and cooled, called the act of "tempering;" this property again appears to connect the imponderable and invisible agent heat with the assumption of some of the most important qualities of steel.

The analyses of steel indicate the presence of from 1·94, 1·7, 1·72, 1·43, 1·13, ·62 of carbon; so that from about a half to two per cent. of that element appears to be amply sufficient to impart the properties of steel to iron, provided that peculiar state of combined carbon and probably nitrogen is obtained, which is not yet quite understood by scientific men.

Fifth Series.

Solutions of iron are used by dyers to produce the colour termed "iron buff," which is obtained by passing a piece of calico cloth through a solution of a persalt of iron, and then into one of an alkaline carbonate. Different shades are obtained by varying the strength of the solutions.

Prussian blue is produced on cloth by first passing it through a solution of acetate of iron (iron liquor), and afterwards into one of ferrocyanide of potassium, or it is obtained as an independent pigment by precipitating a protosalt of iron with the red ferricyanide of potassium, or a persalt with yellow ferrocyanide of potassium.

The addition of a few drops of a strong solution of sulphocyanide of potassium to one of a persalt of iron, produces a blood-red colour, and if the experiment is performed on the surface of a white plate, the appearance of blood is conferred upon the mixture of the two salts. The

almost instantaneous disappearance of the blood-red colour is produced by adding a little solution of tartrate of ammonia.

Ink is prepared by adding a solution of a protosalt of iron to a decoction of nutgalls and logwood, and the following recipe is recommended by the author, who has used it for many years :—

Bruised galls	4 ounces.
Ground logwood	1 „
Sulphate of iron	2 „
Gum arabic	1 „
Water	1 quart.

Boil the galls and logwood in the water, say, for half an hour; make up the quantity lost by evaporation, and strain through coarse calico; dissolve the sulphate of iron in a very little water, then add it to the decoction of galls and logwood and stir vigorously. Put the vessel on one side for a day or two, and stir frequently; pour off or strain through muslin; finally, add the ounce of powdered gum and a few cloves. Lewis recommends with great propriety the use of common white wine (query, South African?) instead of water, and he also advises that a few broken gall nuts and iron nails be placed in the bottle in order to keep the ink in good order.

Sixth Series.

The analysis of iron or an iron ore is usually performed by the wet process, but the whole of the analytical steps to be taken are too complicated to be described in the present elementary work. Supposing it was desirable, for commercial purposes, to determine the per-centage of iron in an iron ore, a given weight of the ore should be fused in a platinum crucible, with four times its weight of pure dry carbonate of soda, and whilst hot, but not red-hot, may be transferred to a porcelain dish containing dilute hydrochloric acid. After all the fused mass is dissolved out of the crucible, the latter may be washed and removed, and the solution gently evaporated to dryness with the previous addition of nitric acid until the whole of the iron is peroxidized. The residue in the dish may now be moistened with hydrochloric acid, and allowed to stand a few minutes; water is then added, the solution filtered, and the matter left on the filter well washed, dried, ignited, and estimated as silica or sand. The clear solution of iron is now precipitated with an excess of ammonia, and the sesquioxide of iron collected on a calico or paper filter, washed with cold and finally with boiling distilled water, until the liquid that passes no longer affects a solution of nitrate of silver. The washed oxide of iron is finally dried, ignited, and weighed, and the iron estimated by the rule of proportion. As the equivalent proportion of sesquioxide of iron (which is equal to 80, and contains 56 parts of metallic iron) is to the weight of the sesquioxide of iron obtained from the above analysis, so is the metallic iron contained in the equivalent proportion to the answer required—viz., the weight of me-

tallic iron in the sesquioxide obtained by the analysis. The sesquioxide of iron obtained by precipitation with ammonia will contain most probably alumina, but this may be separated by the following process. The sesquioxide of iron, after powdering and fusion with carbonate of soda, is dissolved in hydrochloric acid, and precipitated with an excess of boiling potash, the latter dissolves the alumina, and, after filtration, may be again precipitated from it by the addition of an excess of chloride of ammonium. The bulky precipitate of alumina is then collected, washed, dried, ignited, and weighed.

Seventh Series.

Iron is detected with great facility by means of ferrocyanide of potassium, if it is in the state of the persalt; and by ferricyanide of potassium when it exists as a protosalt; and it is precipitated in the very marked condition of *Prussian blue*, soluble in oxalic acid.

Sulphocyanide of potassium produces a blood-red colour with persalts of iron.

Ammonia precipitates the hydrated red oxide from solutions of the persalts of iron.

In all cases of testing for iron, the metal should first be peroxidized by nitric acid.

Sulphuretted hydrogen produces in acid and neutral solutions a precipitate of sulphur, and the peroxide of iron is reduced to the state of protoxide.

Sulphide of ammonium precipitates black sulphide of iron (FeS), which is decomposed by exposure to the air.

Protosalts of iron are precipitated by potash and ammonia in the state of a white, rapidly becoming a dingy-green and reddish-brown precipitate.

Nitric acid added to protosalts produces an increase of colour of a brownish tint, in consequence of the change of the protoxide of iron into sesquioxide.

Perchloride of gold is reduced to the metallic state in the form of a brownish-black powder by the addition of a protosalt of iron.

The protosalts of iron are precipitated by the ferricyanide of potassium ($Fe_2$2 Cfy) as "Prussian blue," which is decomposed by potash into a reddish-brown powder, in consequence of the precipitation of peroxide of iron.

Eighth Series.

Returning again to the all-absorbing topic of iron-mailed ships, the following remarks by Mr. Lynall Thomas, in the *Times*, are most interesting:—

"Notwithstanding that my opinion may be opposed to that of many naval officers of great weight and experience in their profession, I am nevertheless convinced that an iron-cased ship (unless her plates were of a thickness utterly to preclude the possibility of her being a seagoing

ship) might be destroyed from shore batteries, large frigates, or gunboats at distances at which she could be hit with any degree of certainty, say two or three thousand yards, and with guns very little, if at all, heavier than the service 68-pounder gun.

"If Government will find the money I will engage to furnish them with guns and projectiles which shall penetrate the sides of a vessel cased with iron plates $4\frac{1}{2}$ inches thick, at the distance I have named.

"To show that this is no vain boast, I will explain how it can be done.

"It has been proved that a 68lb. shot of wrought iron will penetrate a $4\frac{1}{2}$-inch iron plate with facility within the distance of 100 yards, the initial velocity of the shot being less than 1800 feet a second.

"Those who know anything of the theory of projectile force will be aware that a shot of 170lb. weight, striking an object with a velocity of 1100 feet a second, would have a penetrating power quite equal to that of the 68lb. shot, while the general effect of the blow would be enormously greater.

"According to the ordinary method of calculation, therefore, this shot should penetrate an iron plate at almost any distance within its range with the same facility as would a 68lb. shot at a distance of 100 yards. No iron-cased ship could come within the range of guns similar to the one I have referred to without the risk of destruction, unless, as I remarked, the plates of iron were so thick as to render the vessel an inert, floating mass."

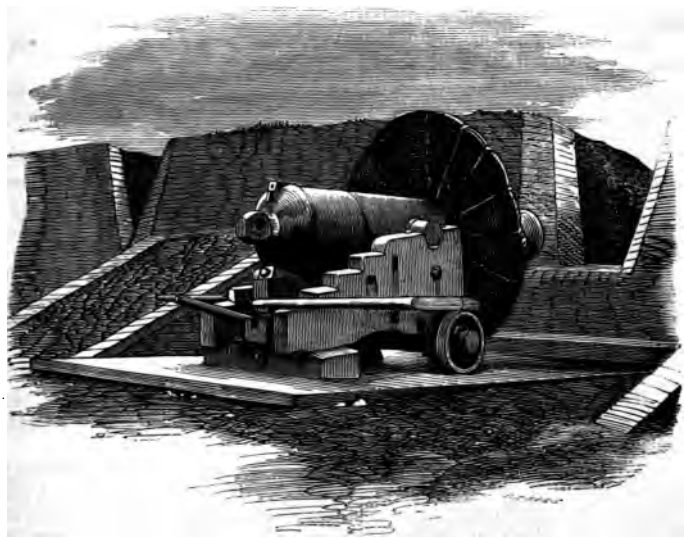


Fig. 219. Eight-inch Gun on Rear-chock Carriage, covered by the Russian Mantelet.

METALS UNKNOWN TO THE ANCIENTS.

Fig. 220. A Brick Field. Clay the source of Aluminium.

CHAPTER XI.

ALUMINIUM.

THIS metal, which has lately become very popular, derives its name from alumina, so called by Morveau about 1760, because it is obtained in the greatest state of purity from alum. Some years previously Margraff had shown that the base of alum is an earth of a peculiar nature, and quite different from all others, being an essential ingredient and characteristic of every variety of clay, and imparting to it the property of tenacity and plasticity by which good clay may be moulded into almost every imaginable shape, and after being burnt, is rendered hard and durable. The earth which conferred these properties was called *argil*, and hence, when speaking of a rock which contains an excess of clay, it is commonly said to be *argillaceous*.

The sources of the metal aluminium are, therefore, boundless, and it lies at the doors of the richest and poorest members of society; the universality of its presence enables us partly to realize the idea of Whittington; and if the streets of London are not paved with gold, they do contain an abundance of the beautiful silvery-like metal aluminium, now being made and sold in jewellers' shops, and used for ornamental purposes as brooches, bracelets, chains, &c., &c. Directly the announce-

ment was made of the discovery of the means of procuring aluminium from clay in any quantity, the author was favoured by an offer of a large clay farm and a loan of a thousand pounds to work it into crops of aluminium. No one but a Dousterswivel could have accepted the tempting chance of comfortable board and lodging and nice country air for a year or so whilst *preparing* the apparatus to produce the aluminium, because (as we shall see presently) there is a very roundabout and expensive chemical process to be conducted before the valuable metal is extracted from the comparatively worthless clay.

There is every reason to suppose that at some early period of the existence of our globe, its outer crust was represented by hard rocks, which have crumbled down in the hand of "old Time," aided by the action of water in the shape of rain and ice, and the consolidated snow of the glacier grinding its slow and solemn path from the topmost peaks of the highest mountain ranges. These crumbled and roughly-powdered rocks have given us our various qualities of soils, the light containing an excess of the sandy element; the stiff or heavy soil, the argillaceous, clayey, or aluminium-bearing earth. Amidst such an abundant choice of the raw material to work upon, it might be thought only necessary to take a spade and remove a lump of clay from the field to the laboratory; but it must be remembered that this raw material is somewhat too coarse and crude—it contains the alumina (the source of the metal) in a very insoluble form; the silica or sand is abundant, and would require to be separated, and the clay itself is inconveniently bulky, in consequence of the large quantity of water naturally contained within it, and amounting at least to fifty per cent. of the whole weight. Aluminium could certainly be obtained direct from clay, if the latter was first calcined, so as to make it dry and porous, but not to fuse its particles, and then digested for months with dilute sulphuric acid; the latter would dissolve and combine with the alumina, and form sulphate of alumina, and when this solution is mixed with a potash salt, such as sulphate of potash or chloride of potassium, the alum may then be crystallized out. A particular mineral is therefore preferred and selected, called alum slate, which has a bluish- or greenish-black colour, and contains a certain proportion of iron pyrites or sulphide of iron; this substance is decomposed by exposure to the air into oxide of iron and sulphuric acid, and the latter attacks the alumina and forms the basis of alum, which is a double salt, being the sulphate of alumina and potash.

This alum slate is usually found in the neighbourhood of coal, and indeed usually contains more or less bituminous matter; sometimes the heat generated by the decomposing iron pyrites is so great that the mineral takes fire, and originates those great natural fires in coal mines which in former times were allowed to rage for years in "the waste" of certain coal fields, but are now attacked in a scientific manner, and extinguished by the method first proposed and carried out by Mr. Goldsworthy Gurney, and described in the "Playbook of Science."

The presence of bituminous matter in the alum slate imparts that porosity and openness of the pores which admits the oxygen of the

air to the iron pyrites, and renders a smaller quantity of fuel sufficient for the purpose of setting it on fire.

The ordinary alum rock is mixed with small coal, cinders, &c., and formed into heaps and burnt precisely in the same manner as those heaps of clay already alluded to, and visible in any new London neighbourhood where that sticky soil is abundant. The combustion of the alum rock heaps is kept as slow as possible, and water occasionally added. It is conducted, of course, on a gigantic scale, so that the works are never stopped for want of calcined alum rock. After burning, the heaps are left exposed to the weather, care of course being taken that the rain falling on and passing through the mass shall be conveyed by proper drains and channels to the lixiviating pans or cisterns, where the burnt rock, after "weathering," is digested with water to dissolve out the sulphate of alumina. The cisterns are arranged like a series of terraces, so that the cost of labour in lifting and pumping is avoided. The weak solution passes in succession from one cistern to the other, all of course containing burnt alum rock; and when sufficiently strong, it is passed into proper receptacles, and a salt of potash (such as sulphate of potash from the aquafortis makers, or chloride of potassium) added; the potash salt unites with the sulphate of alumina, and produces crystals of sulphate of alumina and potash. These are subsequently recrystallized, and form the alum of commerce, composed of

Sulphate of potash	18·34
Sulphate of alumina	36·20
Water	45·46

Alumina, the sesquioxide of the metal aluminium, is obtained either from the sulphate of alumina, or from common alum, by precipitating the solution with carbonate of ammonia, which throws down a bulky white gelatinous precipitate of the hydrate of alumina; the solution is heated, and the precipitate collected on a calico filter, and washed with plenty of water, redissolved in hydrochloric acid, again precipitated by ammonia, thoroughly washed, and dried at a gentle heat.

Gay Lussac has, however, proposed a much easier mode of obtaining alumina, and recommends that *ammonia* alum be exposed first to a gentle heat, to drive off the water of crystallization; and afterwards to a red heat, which leaves the alumina pure. Ammonia alum is made by substituting sulphate of ammonia for sulphate of potash in the addition to the sulphate of alumina to form alum.

It is evident, from this condensed narrative, that the process of separating alumina from clay is neither an easy nor a rapid one; and then the chasm that divides the oxidized from the pure metal is a wide one, and demands considerable skill to bridge it over.

The reduction of alumina to the metallic state is a process of great interest; and one of the best papers ever read upon this subject is that of the highly respected and talented secretary of the Society of Arts, Mr. Peter le Neve Foster, M.A., and published in the "Journal"

of the Society, February 4th, 1859, from which the following historical table is partly compiled:

1807.—Sir H. Davy discovered, by the agency of electricity, the alkaline metals, one of which (sodium) is the key to the reducing process for aluminium. Gay Lussac and Thénard discovered that potash and soda are decomposed at a white heat by iron; and they contrived a process for obtaining the alkaline metals in larger quantities at a cheaper rate. When this process was known in England, the alkaline metals were made in small quantities, and sold at fabulous prices, and not less than 5*l.* per ounce. Mitscherlich, Brunner, Donny, and Mareska improved the process further, so that the alkaline metals were sold for about 30*s.* per ounce.

1854.—M. H. Sainte-Claire Deville, assisted with funds from the Emperor Napoleon III., prepared sodium so that the price fell to 7*s.* 6*d.*, then to 5*s.* per ounce.

1858.—Gerhard, at Battersea, by still further improvement, manufactured sodium at 1*s.* per ounce, or 16*s.* per pound avoirdupois.

In the first table the reader may glance at the gradual fall in the price of sodium, due to the improved methods of production; and in the second table the history of the preparation of aluminium is apparent.

1807.—Sir H. Davy did not obtain aluminium sufficiently pure to investigate its properties. Alloys were, however, formed with it that proved the existence of the metal.

1826.—Berzelius and Œrsted failed to obtain aluminium.

1827.—Œrsted succeeded in obtaining aluminium from the chloride of aluminium; and the following notice, copied from Hensman's "Répertoire de Chimie," appears in the "Philosophical Magazine" for 1827, p. 391: "M. Œrsted is stated to have obtained the metal alumina (*sic*) by employing the chloride of that earth. Pure alumina is heated to redness, and then intimately mixed with powdered charcoal; the mixture is introduced into a porcelain tube, and after heating to redness, dry chlorine gas is passed over it. The charcoal reduces the alumina, the metal combines with the chlorine, and oxide of carbon is also formed. The chloride of aluminum is soft, crystalline, and evaporates at a little above the temperature of boiling water; it readily attracts moisture from the air, and becomes hot when water is added to it. By mixing with an amalgam of potassium, containing much of the latter, and immediately heating the mixture, chloride of potassium is formed, and the metal of the alumina combines with the mercury. The amalgam quickly oxidizes by exposure to the air. Being subjected to distillation out of the contact of air, the mercury is

volatilized, and a metallic button is left, which *has the colour and splendour of tin* [they did not take the liberty of comparing it to silver]. M. Œrsted has ascertained many properties belonging to the new metal and its amalgam, which he promises to publish speedily."

1828.—Wöhler improved Œrsted's process as follows: "When an attempt is made to heat chloride of aluminum with potassium in a porcelain tube, the action is so strong, and the extrication of heat is so considerable, that the apparatus is instantly broken. I therefore employed a small platina crucible, the cover of which was kept on by a wire of the same metal. At the moment of reduction the crucible became intensely red hot, both within and without, although it was but slightly heated; the metal of the crucible was not sensibly acted upon. The operation may also be effected in a porcelain crucible with a cover attached, and indeed is recommended by Wöhler. . . . . Excess of potassium is to be avoided; for after it was oxidized it would dissolve a portion of the aluminum. The reduced mass is generally completely fused, and is of a blackish grey colour. When all is cold, the crucible is to be thrown into a large vessel of water; a grey powder is soon deposited, which, when looked at in the sunshine, appears to be entirely composed of small metallic plates; the powder is to be washed with cold water, and then dried: it is the metal of alumina."—*Philosophical Magazine*, 1828, p. 149.

1854.—Deville, assisted with funds from the Emperor Napoleon III., repeated Wöhler's experiments, and substituted sodium for potassium, the combining proportion of Na being 23, whilst that of K is 39·2, and thus reduced the quantity of the alkaline metal required to nearly one-half. Deville's vessels of porcelain are only a repetition of Wöhler's. To produce the chloride of aluminium, Deville forms a mixture of alumina (prepared by Gay Lussac's process—viz., by heating ammonia alum red-hot) and charcoal made into a paste with oil, which is heated to a red heat in upright tubular retorts of fireclay, similar to those used in the manufacture of coal gas; and whilst in this state, a current of chlorine gas is caused to pass into the retort, when chemical reactions take place, and the chloride of aluminium sublimes over, and is condensed in proper vessels. This process of Deville's, it will be seen, only differs from that proposed by Œrsted twenty-seven years before, in the addition of *oil* to the charcoal and alumina, and in the employment of a gas retort instead of a porcelain tube. The reduction of the metal from the chloride was performed by Deville in the following manner: "A tube of Bohemian glass, 36 inches long, and about one inch in diameter, is placed in a

combustion furnace constructed for the purpose of heating the tube. Chloride of aluminium is placed in one end of the tube, and at the same extremity a current of dry hydrogen gas is made to enter the tube, and sustained till the operation is finished. The chloride is now gently warmed by pieces of hot charcoal, in order to drive off any hydrochloric acid it may contain; porcelain trays filled with the metal sodium are introduced into the other end of the tube, and the heat augmented by fresh pieces of glowing charcoal, until the vapour of the sodium decomposes that of the chloride of aluminium. Intense ignition usually attends this reaction. At length, the metal aluminium is libe-

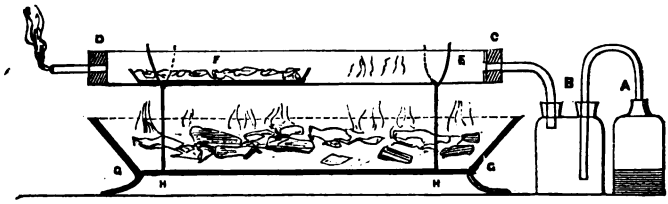


Fig. 221. A. Hydrogen generator. B. Chloride of calcium bottle, for drying the gas. C, D. The Bohemian-glass tube, containing the chloride of aluminium at E, and the tray of sodium at F. G G. The chafing-dish, containing burning charcoal. H, H. Wire supports for the tube.

rated and forms buttons, which are found in the tray, adhering to a substance consisting of the mixed chlorides of aluminium and sodium. The tray with its contents is now transferred to a porcelain tube, through which hydrogen gas is passed. At a red heat, the double chloride distils into a receiving vessel attached to the tube for the purpose; the buttons of aluminium are collected, washed with water, and subsequently fused together under a flux consisting of the double chloride."

1855.—M. Paul Morin so far improved Deville's process as to conduct it, like Wöhler, in a crucible. The same year Dr. Percy suggested the use of the mineral cryolite, (which is a double fluoride of aluminium and sodium), as the ore from which the metal could be obtained, and experiments were made by the late Mr. Allan Dick with this mineral, and the metal procured from it by the following process: "A platinum crucible is first lined with magnesia, by ramming the same hard in, and subsequently cutting all out but a thin lining. Into this alternate layers of cryolite and sodium are placed, with a thickish layer of cryolite on the top. The crucible is covered with a tight-fitting lid, and heated

to redness for about half an hour over the air blowpipe. When cold, it is placed in water, and after soaking for some time, the contents are removed, crushed in a mortar, and washed by decantation. Two or three globules of aluminium tolerably large, considering the scale of the experiment, are obtained along with a great number of very small ones. The large ones were melted together under chloride of potassium."

Professor Rose, of Berlin, speaks highly of Dr. Percy's process, and says, "I am of opinion that cryolite is the best adapted of all the compounds of aluminium for the preparation of this metal. It deserves the preference over chloride of aluminium and chloride of aluminium and sodium, and it might still be employed with great advantage, even if its price were to rise considerably."

1858–59.—Mr. Gerhard, an Englishman, established a factory at Battersea where aluminium and sodium are prepared in large quantities, and at a cheaper rate than they can be procured in Paris. Mr. Gerhard uses 270 parts by weight of powdered cryolite, mixed with 150 of common salt, and into this mixture are placed 72 parts of sodium cut into small pieces. The whole is then thrown into a heated earthenware crucible, previously lined with a melted mixture of cryolite and salt, which mixture is also immediately poured over the contents of the crucible, covering them to some little depth; finally, the cover is put on. The crucible is now subjected to a full red heat for two hours, and when the pot is uncovered, the melted mixture is well stirred and then poured out. The buttons of aluminium are found mingled with the slag, and may be easily melted together by heating them in a crucible with common salt. Theoretically, the quantity of aluminium obtainable by this process should be one-third of the weight of the sodium employed, but practically such a result is never attained, and it does not extend beyond the mean between one-third and one-fourth of the sodium used. Previous to Deville's labours, aluminium sold at the rate of 40*l.* sterling for 35 ounces avoirdupois; in 1856, when Deville came to England, the price was reduced to a much lower rate, and the metal is now to be bought at about 3*s.* 9*d.* per ounce, or 6*l.* 10*s.* for 35 ounces.

One of the most pleasing reminiscences of the author is connected with the metal aluminium, and he records with gratitude the gracious condescension of the Emperor Napoleon III., who not only deigned to answer his application for a specimen of the then rare and much-sought-after metal, but also forwarded to him a bar of aluminium, which was exhibited at the Royal Polytechnic for many months, to the great delight of the curious, who were all most anxious to handle and touch the metal made from *clay*.

The following letter was graciously sent with the bar of aluminium:—

"Cabinet de L'Empereur, Palais des Tuileries,
le 29 Juillet, 1855.

"MONSIEUR,—L'Empereur a daigné accueillir favorablement votre demande. J'ai l'honneur de vous envoyer, par son ordre, un morçeau d'aluminium, destiné à la collection de métaux de l'Institut Polytechnique. Je vous prie de m'accuser réception de cet envoi.

"Recevez, Monsieur, l'assurance de mes sentiments très-distingués.

"Le Sous-chef du Cabinet de l'Empereur,
"ALBERT DE DALMAY.

"Mr. John Pepper."

Fig. 222. The Bar of Aluminium presented by the Emperor Napoleon III. to the Author, during his Management of the Royal Polytechnic.

In an admirable lecture delivered at the Athenæum, Bristol, by Dr. Griffin, that gentleman made the following remarks upon the probable uses of aluminium, and exhibited a medal commemorative of her Majesty's visit to Paris, struck for him at the Imperial Mint of France, in that metal. After explaining the process of obtaining the aluminium, "Dr. Griffin referred to the experiments of M. Deville, and the encouragement afforded him by the French Academy, who voted the sum of two thousand francs to defray the cost of continued researches. Deville soon procured enough of the metal to cast several ingots and have a medal struck, which he presented to the Emperor, who, with that en-

lightened spirit which characterizes the French in such matters, authorized experiments on a large scale to be continued at his own cost. It was worthy of remark, that from the first, Deville had repudiated all affectation of mystery, or claim to exclusive pecuniary profit; all his results had been constantly reported to the Institut, and his operations themselves thrown open to scientific and practical men. That liberality of feeling is one of the most pleasing features of the French character; in Paris any intelligent inquirer was everywhere welcome, and met with nothing but courtesy and kindness. M. Deville was not in Paris during the lecturer's stay, but at his splendid laboratory in the Ecole Normale every information on all points connected with his researches was freely rendered, and he took sketches of the apparatus. Considerable quantities of the metal had been procured by M. Deville, there being in the Paris Exhibition a pile of a dozen bars, besides a variety of articles manufactured from it. The properties of aluminium in its new form were thus described. It was a white metal susceptible of a high polish; its white was not so pure as silver, especially when it had been worked, but had a decided shade of blue, so that it was hardly likely to replace silver for ornamental plate; but it would make capital mustard and egg spoons, as it was not in the least affected by sulphuretted compounds, whether gaseous or otherwise, which so instantly blackened silver. It retains its lustre in the air, whether moist or dry, for any length of time and at all temperatures; even when kept melted it hardly oxidized like zinc or tin, though each fragment became covered with an extremely slight violet film of oxide, which prevented its running together unless stirred up with a rod. If covered with chloride of potassium, or the double chloride of aluminium and sodium, this superficial oxidation was prevented and the smallest globules united in one. Not only had boiling water no action upon pure aluminium, but even diluted sulphuric acid and strong nitric acid, which vehemently attacked silver, had no action upon it in the cold, and it was not sensibly affected by being plunged into melted nitre, potass, or sulphuret of potassium—a threefold test which no other metal, not even gold or platinum, can withstand, and hence it would be extremely valuable in certain laboratory vessels. Muriatic acid, however, rapidly dissolved it, even in the cold, from its powerful attraction for chlorine. Alkaline solutions also acted on it, and were, in fact, useful for cleaning it. The metal was nearly as hard as iron, but could be softened by annealing; it had great rigidity and tenacity, and when a bar was broken across, it showed a fine-grained fracture, like cast steel. It could be turned, chased, and filed with the greatest facility, and without clogging the tools. In the Paris Exhibition there were several examples of its working capabilities. M. Christofle, the well-known Parisian gold- and silversmith, exhibited forks and spoons, and also a cup made from it; and, to show its hardness and strength, it might be mentioned that this cup, though quite thin, could be allowed to fall out of the hand on to a stone pavement without being indented. Aluminium could be drawn into wire as fine as a hair, and rolled into extremely thin sheets. Small traces

of iron much impaired its malleability, and rendered its colour bluer and duller; when considerably impure it became much more markedly crystalline, both on the exterior and in its texture throughout. It could be plated on copper, and soldered with ease. It melted at a full red heat, about the same as silver, and took a good impression by casting. It also struck admirably under the die, as was better seen in large medals than in the small one produced, which was struck for him with some trouble at the French Mint, through the kindness of the Director, the distinguished chemist, M. Pelouze. He remarked, however, that in future years that would become a notable historical souvenir, being, as it was, a memento of the auspicious and magnificent visit of a sovereign of England to the capital of France, impressed on a material belonging to the same epoch. Thus it would be seen that aluminium fulfilled every requisite for a multiplicity of industrial applications, but it had yet another remarkable feature. Its density was intermediate between that of the alkali metals which floated on water, and the ordinary heavy metals. It was considerably lighter than flint glass, being only two-and-a-half times heavier than water. Thus, bulk for bulk, it was four times as light as silver, and but little more than one quarter the weight of copper. Hence, it had been suggested that, if it could be procured cheaply enough, its hardness, lightness, and incapability of rusting would render it admirably adapted for the helmets and cuirasses of the cavalry; it would make splendid field-guns, as strong as the present ones, and not one-third their weight; and, in sheets, it might serve as an incorrodible roofing, far lighter and more durable than even zinc. It would also admirably replace copper, if not silver, for the purpose of coinage. A crownpiece in aluminium would hardly weigh more than a shilling in silver; or, a piece the size of a penny, about as much as a copper farthing. The same qualities of lightness, hardness, and incorrodibility also fit it excellently for the beams of delicate balances, and the minute weights used in analysis. It would also make admirable utensils for the more delicate operations of cookery, replacing the copper ones, which rendered pickles and soups so poisonously green; it would also form excellent vessels for manufacturing chemists; it being extremely sonorous, would make capital bells, and aluminium coins would have a "ring" equal to those of silver. The present price of aluminium, as retailed by Messrs. Rousseau, was 3*l.* 10*s.* an ounce, but that was merely a fictitious price, the demand for it as a chemical curiosity greatly exceeding the very limited supply, and the makers having to reimburse themselves for much outlay in apparatus and preliminary experiments. In estimating its cost, they must never forget its singular lightness; even at its present price, bulk for bulk, it was ten times cheaper than gold, and only three times the price of silver; but, in looking forward, he could see no improbability in its being made for 8*s.* or 10*s.* a pound, and then it might at once replace copper for coinage, for it is nearly four times as light, so that pieces of half the present size would be of the same value as now. Time alone could decide the question of the cost of the metal. Much depended on the scale on

which any product was manufactured. Phosphorus, which in its early days, was an object of curiosity like aluminium now, sold for a guinea an ounce; fifteen years ago it was as much per pound; now, though its preparation was difficult and dangerous, it was about 3*s.* 6*d.* a pound, solely from its commercial demand for the manufacture of that insignificant but useful little article the lucifer-match. Aluminium formed alloys with most of the metals, but hardly at all with lead, and it would not in the least amalgamate with mercury, which might be useful in some of its future applications. After dwelling for a short time upon these alloys, which he said had not been much studied, the lecturer closed his remarks by observing that Mr. Gore, an able electro-chemist of Birmingham, had presented the Society of Arts with specimens of copper and brass, coated with white and lustrous aluminium and silicium by the usual electro-plating process from the solution of alumina, obtained by boiling pipe-clay with sulphuric acid, or from the common siliceous sandstone dissolved by hydrofluoric acid, so that silicium might hereafter be destined to play as prominent a part as its sister aluminium; and assuredly it was a proud triumph for chemistry, amidst the countless benefits she had conferred on mankind, that she had wrung their hidden metals from despised clay and paving-stones to add to the comforts and ornament of their daily life, thus, as it were, bringing home Peru and Mexico to their very doors."

Aluminium appears to take an intermediate position between the precious metals and the common ones, and Professor Graham considers that it ought to stand at the head of the common metals. It possesses some properties analogous to those belonging to iron, such as a *passive* state in nitric acid; it is also slightly magnetic, and acquires by pressure some of the elasticity of iron. Aluminium combines with carbon and silicium, forming brittle and friable compounds somewhat similar to those procured from iron when combined with the same elements, and, like iron, it does not unite with mercury.

One of the chief objections urged against the use of aluminium is its extreme liability to abrasion; but even then, its alloys are proved to be most valuable, especially the alloy with copper, or "aluminium bronze," as it is considered that if this could be procured sufficiently cheap, superior cannon might be cast of it.

The employment of aluminium by dentists appears to be limited to the use of the cast metal, as the forged aluminium is frequently attacked and destroyed by the saliva of the mouth. Aluminium and iron may probably form alloys which will be of the very highest importance. At the present time aluminium is to be had in London, from any of the silversmiths, at a very cheap rate, made into jewellery and ornaments of various kinds, bracelets, combs, pins, seals, penholders, tops of inkstands, porte-monnaies, shirt-studs, harness, statuettes, candelabra, candlesticks, bells, tubes, &c.

Experiments with Aluminium.

First Series.

The combining proportion of this metal is 13·7, and its specific gravity is 2·6, being nearly that of glass; it is malleable and ductile, and possesses considerable tenacity; it conducts electricity eight times better than iron, and is considered to be about equal to silver in that respect. It melts at a temperature between that required to fuse zinc and silver. It is not readily attacked by oxygen gas; and Deville ascertained that it could be exposed for a lengthened time to the action of a current of air in the cupelling furnace without undergoing any change.

The only oxide of aluminium known at the present time is the sesquioxide, called alumina, having the same relation to oxygen as the sesquioxide of iron, and represented by the formula Al_2O_3. The manner of obtaining this oxide from ammonia-alum has already been explained at p. 397. The state of aggregation of the metal aluminium has no doubt a great deal to do with its combustibility in oxygen. Deville, as already observed, exposed some melted aluminium in a cupel, but did not succeed in setting it on fire; but Wöhler, using the finely-divided metal in his experiments, observed that when the aluminium was heated to redness in the air, it took fire and burnt with great brilliancy into white and tolerably hard alumina. He also states that when it is projected on the flame of a candle, it emits sparks as brilliant as those of iron burning in oxygen gas. It also burns in oxygen gas with a splendour which the eye can hardly support, and with so much heat that the resulting alumina is, in part at least, fused into yellow fragments, which are as hard as corundum, and not only scratch, but absolutely cut glass. In order to obtain this combustion in oxygen, it is necessary first to heat the finely-divided aluminium red hot before plunging it into the gas. Indeed, these results are very similar in effect to those obtained with antimony or bismuth in chlorine gas; when these metals are introduced in lumps into the gas, the action is slow and unaccompanied with the evolution of fire; but if they are first reduced to powder, and then dropped into the chlorine gas, they take fire and produce at once the chlorides of these metals.

Alumina appears to perform the part of an acid, and combines with potash, magnesia, baryta, strontia, &c., forming aluminates of these bodies. When first precipitated as an hydrate of alumina, it is extremely bulky, and very much resembles jelly or pectic acid, and if allowed to dry slowly, it gradually contracts into a substance that looks like fine glue. Dr. Thompson found that 100 grains of precipitated alumina left to dry on a paper filter during two months, at a temperature not exceeding 60° Fah., retained so much water, that when heated red hot it lost 51·3 grains of water, or rather more than half its weight.

After being heated red hot, a great condensation of water appears to take place within its pores when cold; and Berzelius found that 100 parts, after being ignited, gained 15½ grains from a dry atmosphere,

and 33 grains from a humid one; hence, in estimating and weighing this substance in analysis, great care must be taken to prevent it absorbing moisture. Like sponge, alumina shrinks as it yields up its water, and upon this property is founded the pyrometer of Wedgwood, which is intended to measure high degrees of heat by the amount of the contraction of regularly shaped pieces of china clay; and as we have had frequent occasion to speak of the temperature at which metals fuse, it may be interesting here to describe the late Professor Daniell's improvement on the pyrometer of Wedgwood. The latter instrument afforded incorrect results; partly on account of the difficulty of obtaining clay of uniform composition, and partly because the principle upon which it is founded is not a correct one, for clay will contract as much by a long-continued *low* heat as by a short continuance of a *high* one. Daniell's *Register Pyrometer* consists of two parts, which may be distinguished as the register and the scale. The register is a solid bar of blacklead earthenware, highly baked; in this a hole is drilled, into which a bar of any metal, six inches long, may be dropped, and which will then rest upon its solid end. A cylindrical piece of porcelain, called the index, is then placed upon the top of the bar, and confined in its place by a ring or strap of platinum passing round the top of the register, which is partly cut away at the top and tightened by a wedge of porcelain. When such an arrangement is exposed to a high temperature, it is obvious that the expansion of the metallic bar will force the index forward to the amount of the excess of its expansion over that of the blacklead, and that, when again cooled, it will be left at the point of greatest elongation. What is now required is the measurement of the distance which the index has been thrust forward from its first position; and this, though in any case but small, may be afforded with great precision by means of the scale. This is independent of the register, and consists of two rules of brass, accurately joined together at a right angle by their edges, and fitting square upon two sides of the blacklead bar. At one end of this double rule a small plate of brass projects at a right angle, which may be brought down upon the shoulder of the register, formed by the notch cut away for the reception of the index. A moveable arm is attached upon this frame, turning at its fixed extremity upon a centre, and at its other carrying an arc of a circle whose radius is exactly five inches, accurately divided into degrees and thirds of a degree. Upon this arm, at the centre of the circle, another lighter arm is made to turn, one end of which carries a nonius with it, which moves upon the face of the arc, and subdivides the former graduation into minutes of a degree; the other end crosses the centre, and terminates in an obtuse steel point, turning inwards at a right angle.

When an observation is to be made, the metallic bar is placed in the cavity of the register, the index is to be pressed down upon it and firmly fixed in its place by the platinum strap and porcelain wedge. The scale is then to be applied by carefully adjusting the brass rules to the sides of the blacklead bar, and fixing it by pressing the crosspiece *a* (Fig. 223) upon the shoulder; holding the whole together steadily in the

left hand, the moveable arm should be so placed that the steel point (*k*) of the other leg of the compasses may rest upon the edge of the porcelain

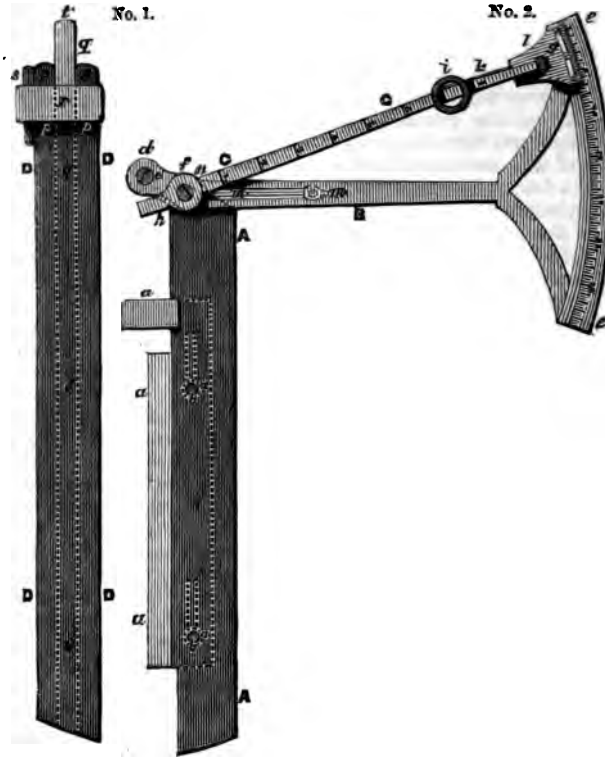


Fig. 223. Daniell's Pyrometer. No. 1 is the register. D D D D is the blacklead bar with its cavity, o o. At *p p p p* it is cut away to the depth of half the bore. *q q* is the porcelain index, which is placed upon the top of the metallic bar, and confined to its place by the pressure of the platinum strap *r*, so acting by the force of the small porcelain wedge *s*. No. 2 represents the scale. A A is the principal brass rule, upon the under side of which the frame *a a a a a a* is adjusted by the screws *b b*, and which supports upon its bent extremity *c*, the arm B moving upon the centre *d*, and terminating in the arc of the circle *e e*. C C is the lighter arm moving upon the centre *f* upon the arm B, and carrying at one end the nonius *g*, and at the other the steel point *h*, the distance of which from the centre *f* is exactly half-an-inch, or one tenth of the radius *f g*, and equal to the distance of the two centres *f d*. I is a small lens, represented as lying down, but which may be raised by the centres *k* and *l* perpendicularly above the nonius to facilitate the reading. *m m* is the steel spring, which, being fixed in a cavity cut out of the arm B, presses upon a small pin *n* on the arm C, and throws the radius back to the commencement of the arc.

index, against which it will be pressed with some force by the spring; then, moving the arm gently forward with the right hand, the point will slide along the end of the index till it drops into a small cavity (*t*) formed for its reception, and which exactly coincides with the axis of the metallic bar in the register, and the centre of motion of the compasses on the brass rule. The minute of the degree must then be noted which the nonius indicates upon the arc. A similar observation must be made after the register has been exposed to an increased temperature and again cooled; and the number of degrees or minutes which the nonius will then mark will, by a simple calculation from the known length of the radii and angle, give the length of the chord comprised between the original position of the compasses and the point to which they have moved in the distance which the index has been forced forward. "Such an operation," says Daniell, "appears complex in the description, but is in fact extremely simple after a little practice, and does not require more than a few seconds for its performance. The scale of the pyrometer being completely detached from the part which is exposed to the fire, obviates one important objection which has always been made to other contrivances of the same nature, from the uncertain degree of heat and expansion to which they are liable, while the simplicity of that part of the arrangement which alone is subjected to great heats, renders it little liable to injury; and, together with the cheapness of the material of which it is constructed, occasions but a trifling expense for replacing it when injured."—*Phil. Mag.*, 1831.

Second Series.

Chlorine, bromine, and fluorine unite with aluminium. The preparation of the chloride has already been explained; and as the bromide and fluoride of aluminium do not present any very interesting chemical features, the bare mention of them may be sufficient here. The "topaz" consists almost entirely of fluoride of aluminium united with alumina.

Third Series.

Alumina is the cheapest and the most extensively employed of all mordants for fixing colouring matters on cotton, &c. Four kinds of solutions are used for this purpose: viz., 1. A solution of common alum. 2. A solution of common alum, partly neutralized with an alkali, called basic alum. 3. A solution of alumina in acetic acid, called "red liquor." 4. A solution of alumina in caustic potash, called aluminate of potash. Cotton cloth, washed free from stiffening, steeped in a solution of alum, partly dried, and dipped in a decoction of "fustic," the wood of the *Morus tinctoria*, affords a much brighter yellow than if the cloth had not been prepared with the mordant.

A piece of cotton cloth impregnated with basic alum, and dipped in a hot infusion of cochineal, is dyed a beautiful crimson.

Another piece of cloth dipped in acetate of alumina ("red liquor") affords a beautiful orange, if placed in a mixed decoction of cochineal

and quercitron; the exact shade can only be acquired by practice and a nice adjustment of the quantities of the materials used.

When a piece of cloth saturated with the aluminate of potash is exposed to the air, and especially in occupied rooms, the carbonic acid in the atmosphere is *entirely* absorbed, combines with the potash, and the alumina is precipitated in the fibre of the cloth; hence the importance of one of the stages of mordanting cloth—viz., "hanging," or "ageing," and the free exposure of the goods to plenty of air. The alumina deposited in this manner has a peculiar affinity for colouring matter.

Fourth Series.

Alumina unites with silicic acid, and forms a most valuable series of natural earths and clays, which are employed for a great number of purposes, and especially in the fabrication of pottery and porcelain. Amongst the minerals that consist of alumina and silica are to be named pumice-stone and china clay; and it is from the best description of clay that those beautiful works of art called Parian or statuary porcelain are made by the famous house of Copeland, in Bond-street.

The author is indebted to Mr. Frederick Battam for the following interesting facts in connexion with this manufacture:—

"*Statuary Porcelain.*—The articles under the head of 'Statuary Porcelain' are produced by 'casting.' As the most direct mode of illustrating this process, let us suppose the object under review to be a figure or group, and this we will assume to be two feet high in the model. The clay, which is used in a semi-liquid state, about the consistency of cream, and called 'slip,' is poured into the moulds forming the various parts of the subject (sometimes as many as fifty); the shrinking that occurs before these casts can be taken out of the moulds (which is caused by the absorbent nature of the plaster of which the mould is composed) is equal to the reduction of one inch and a half in the height. These casts are then put together by the 'figure-maker;' the seams (consequent upon the marks caused by the subdivisions of the moulds) are then carefully removed, and the whole worked upon to restore the cast to the same degree of finish as the original model. The work is then thoroughly dried, to be in a fit state for firing, as, if put in the oven while damp, the sudden contraction consequent upon the great degree of heat instantaneously applied, would be very liable to cause it to crack; in this process it again suffers a further loss of one inch and a half by evaporation, and it is now but one foot nine inches. Again, in the 'firing' of the 'bisque' oven, its most severe ordeal, it is diminished three inches, and is then but eighteen inches high, being six inches, or one fourth less than the original. Now, as the contraction should equally affect every portion of the details of the work, in order to realize a faithful copy, and as added to this contingency are the risks in the oven of being 'over-fired,' by which it would be melted in a mass, and of being 'short-fired,' by which its surface would be imperfect, it is readily evident that a series of difficulties present them-

selves, that require considerable practical experience successfully to meet.

"The moulds are made of plaster of Paris, which, when properly prepared, has the property of absorbing water so effectually, that the moisture is extracted from the clay, and the ware may be removed from the mould or 'delivered' with care and rapidity. Prior to use, the plaster (gypsum) is put into long troughs, having a fire running underneath them, by which means the water is driven off, and it remains in a state of soft, fine powder; and if its own proportion of water be again added to it, it will immediately set into a firm, compact body, which is the case when it is mixed to form the mould.

"The following are the degrees of temperature in which the different branches work:—

Plate-makers' hothouse	108°	Fahrenheit.
Dish-makers' hothouse	106°	„
Printers' shop	90°	„
Throwers' hothouse	98°	„

The workmen for whom the temperature of the 'hothouse' is graduated require that heat for drying their work and getting it off the moulds. The outer shops in which they work may be from five to ten degrees less.

"*Printing.*—There are two distinct methods of printing, in use, for China and earthenware—one is transferred on the 'bisque,' and is the method by which the ordinary printed ware is produced, and the other is transferred on the glazed. The first is called 'press printing,' and the latter 'bat printing.' The engraving is executed upon copper plates, and for 'press' printing is cut very deep, to enable it to hold a sufficiency of colour to give a firm and full transfer to the ware. The printer's shop is furnished with a brisk stove, having an iron plate upon the top, immediately over the fire, for the convenience of warming the colour while being worked, also a roller, press, and tubs. The printer has two female assistants, called 'transferers,' and also a girl called a 'cutter.' The copper-plate is charged with colour, mixed with thick boiled oil, by means of a knife and 'dabber,' while held on the hot stove-plate, for the purpose of keeping the colour fluid; and the engraved portion being filled, the superfluous colour is scraped off the surface of the copper with a knife, and is further cleaned by being rubbed with a 'boss' made of leather. A thick firm oil is required to keep the different parts of the design from flowing into a mass or becoming confused while under the pressure of the rubber in the process of transferring. A sheet of paper of the necessary size, and of a peculiarly thin texture, called 'pottery tissue,' after being saturated with a thin solution of soap and water, is placed upon the copper plate, and being put under the action of the press, the paper is carefully drawn off again (the engraving being placed on the stone), bringing with it the colour with which the plate was charged, constituting the pattern. This impression is given to the 'cutter,' who cuts away the super-

fluous paper about it: and if the pattern consists of a border and centre, the border is separated from the centre, as being more convenient to fit to the ware when divided. It is then laid by a transferrer upon the ware, and rubbed first with a small piece of soaped flannel, to fix it, and afterwards with a rubber formed of rolled flannel. This rubber is applied to the impression very forcibly, the friction causing the colour to adhere firmly to the 'bisque' surface, by which it is partialled imbibed; it is then immersed in a tub of water, and the paper washed entirely away with a sponge; the colour, from its adhesion to the ware, and being mixed with oil, remaining unaffected. It is now necessary, prior to 'glazing,' to get rid of this oil, which is done by submitting the ware to heat in what are called 'hardening' kilns, sufficient to destroy it and leave the colour pure. This is a necessary process, as the glaze, being mixed with water, would be rejected by the print while the oil remained in the colour.

"The 'bat' printing is done upon the glaze, and the engravings are, for this style, exceedingly fine, and no greater depth is required than for ordinary book engravings. The impression is not submitted to the heat necessary for that in the 'bisque;' and the medium of conveying it to the ware is also much purer. The copper-plate is first charged with linseed-oil, and cleaned off by hand, so that the engraved portion alone retains it. A preparation of glue being run upon flat dishes about a quarter of an inch thick, is cut to the size required for the subject and then pressed upon it, and being immediately removed, draws on its surface the oil with which the engraving was filled. The glue is then pressed upon the ware with the oiled part next the glaze, and being again removed, the design remains, though, being in a pure oil, scarcely perceptible. Colour, finely ground, is then dusted upon it with cotton-wool, and a sufficiency adhering to the oil, leaves the impression perfect, and ready to be fired in the enamel kilns.

"*Enamel Painting.*—Enamel colours are metallic oxides incorporated with a fusible flux: gold precipitated by tin furnishes the crimson, rose, and purple; oxides of iron and chrome produce reds; the same oxides yield black and brown, also obtained from manganese and cobalt; orange is from oxides of uranium, chrome, antimony, and iron; greens from oxides of chrome and copper; blues from oxides of cobalt and zinc. The fluxes are borax, flint, oxide of lead, &c. They are worked in essential oils and turpentine, and a very great disadvantage under which the artist labours is, that the tints on the palettes are in most cases different to those they assume when they have undergone the necessary heat, which not only brings out the true colour, but also, by partially softening the glaze and the flux, causes the colour to become fixed to the ware. This disadvantage will be immediately apparent in the case where a peculiar delicacy of tint is required, as in flesh tones, for instance; but the difficulty does not end here, for, as a definite heat can alone give to a colour a perfect hue, and as the colour is continually varying with the different stages of graduated heat, another risk is incurred—that resulting from the liability of its receiving the heat

in a greater or less degree, termed 'over-fired' and 'short-fired.' As an instance of its consequence, we will cite rose-colour or crimson, which, when used by the painter, is a dirty violet or drab; during the process of firing, it gradually varies with the increase of heat from a brown to a dull reddish hue, and from that progressively to its proper tint. But if, by want of judgment or inattention in the fireman, the heat is allowed to exceed that point, the beauty and brilliancy of the colour are destroyed beyond remedy, and it becomes a dull purple. On the other hand, should the fire be too slack, the colour is presented in one of its intermediate stages, as already described; but in this case extra heat will restore it. Nor must we forget to allude to the casualties of cracking and breaking in the kilns by the heat being increased or withdrawn too suddenly—a risk to which the larger articles are peculiarly liable. These vicissitudes render enamel painting in its higher branches a most unsatisfactory and disheartening study, and enhance the value of those productions which are really successful and meritorious."

Fifth Series.

Alumina, coloured chiefly with oxide of iron, is found crystallized in nature, and is then valued at enormous sums, under the names of the sapphire, the ruby, and the emerald, which are varieties of the very hard mineral termed corundum—a mineral that justly deserves the title of adamant, and in its more common variety is the well known hard substance sprinkled on glazed cotton or paper, and termed emery or scouring paper.

The sapphire is the next in value to the diamond (supposing always that the gem is free from specks or flaws); it is so hard that it is cut with diamond powder, and polished by means of emery. The most highly-prized variety is the Oriental ruby, of a crimson and carmine red colour. The cochineal red variety is the "Balais Ruby," so named from Balacchan, the Indian name of Pegu, where this variety is found. Amongst the beautiful jewels displayed at the first exhibition in Hyde Park were some remarkable specimens of rubies from Hunt and Roskell, the eminent jewellers of Bond-street. One, a large Oriental ruby of an oval shape and of a deep crimson colour, consisting of a mixture of red and purple, and most beautifully cut, weighed 84 grains. Another "Balais" ruby, of an oblong shape, and of a deep pink, very brilliant, and weighing 53 grains, was considered to be unsurpassed in beauty and perfection; likewise sapphires of a still larger size, and one weighing 180 grains, of a light blue colour, and cut in steps with exquisite lustre, will long be remembered by all those who admire precious stones.

It has already been observed at page 295 that natural minerals may be imitated perfectly by artificial processes; and the same remark can be made with respect to these costly jewels. M. Ebelsman, of the Sèvres Porcelain Works, near Paris, has succeeded in making the artificial "ruby;" not, it must be understood, as a copy in glass, but

veritably and honestly out of the same substance (alumina) of which rubies and sapphires are naturally composed. The process consists in employing a solvent which shall first dissolve the mineral or its constituents, and may thus, either upon its removal, or by a diminution of its solvent powers, permit the mineral to aggregate in a crystalline state. The solvents are boracic acid, borax, phosphate of soda, phosphoric acid, &c.; but the first named is that preferred by Ebelsman, who mixes together certain proportions of alumina, magnesia, oxide of chromium, or oxide of iron, and fused boracic acid; these are then placed in a crucible made of refractory alumina enclosed in a second one, and both carefully protected by covers from air, dust, and dirt, and the whole exposed to the intense heat of a porcelain or other furnace. The materials are dissolved in the boracic acid, and then, as the heat is continued, the latter evaporates, and the alumina and colouring materials are found combined and crystallized, and present the exact appearance of the Spinel ruby. In this way crystals having the same form, hardness, colour, specific gravity, composition, and effect on light as the true ruby, the cymophane, and other precious stones, were prepared, and were found to be identical in composition with them.*

Analysis frequently reveals strange and curious truths, and the production of artificial "ultramarine" is another example of the imitation of one of nature's most beautiful mineral works. The "artificial ultramarine" is made by fusing together soda, carbonate of soda, sulphur, silica, ferruginous clay; and the receipt is copied from the natural specimens of this valuable substance, which consists of—

Silica	45·40
Alumina	31·67
Soda	9·09
Sulphuric acid	5·89
Sulphur	0·95
Iron	0·86
Lime	3·52
Chlorine	0·42
Water	0·12
	97·92

When the Spinel ruby weighs sixteen grains it is considered of equal value to a diamond of half the weight. Corundum occurs in a crystallized state, and the author has a good specimen from India, a six-sided prism, about three inches long, and from one inch to an inch and a quarter wide from plane to plane, called the "Sawmee Stone," from the god Sawmee. This mineral is used in India for cutting all precious stones, and when mixed with shellac, forms their only "grindstone;"

* See Annales de Chimie, 1848, tom. xxii. p. 211.

and as the precious stones alluded to are all varieties of this mineral, the analysis of the specimen is given below:—

Alumina	89·0
Silica	9·0
Oxide of iron	2·0
	100·0

In the collection of crown jewels at the Tower of London are some magnificent specimens of the sapphire and ruby, which are well worthy of a visit of inspection, and are very nicely described by the lady at present in charge of them.

Fig. 224. The Crown and Sceptre of England.

Fig. 225. The supposed Origin of the Name of the Metal.

CHAPTER XII.

ANTIMONY.

THE origin of the name of this metal is somewhat peculiar, and in reading Basil Valentine's "Triumphant Chariot of Antimony," it will be noticed that he speaks of the metal "*yet crude, it fattens swine, how?* Therefore let men know that antimony not only purgeth gold, cleaneth and frees it from every peregrine matter, and from all other metals, but also (by a power innate in itself) effects the same in men and beasts. If a farmer purpose in himself to keep up and fatten any of his cattle —as, for example, an hog—two or three days before let him give to the swine a convenient dose of crude antimony, about half a drachm, mixed with his food, that by it he may be purged; through which purgative he will not only acquire an appetite to his meat, but the sooner increase and be fattened. And if any swine labour with a disease about his liver, antimony causeth it to be dried up and expelled." It is said that certain worthy monks, having experimented upon some hogs with anti-

mony, discovered that it hastened their fattening, and, with a laudable desire to avoid the effects of fasting, they treated themselves to the same medicament, which in their case unfortunately proved fatal; and hence the origin of the name of antimony—*αντι, against*, and *μονος, one who lives alone, a monk.**

Although, apparently, not acquainted with the metal, the ancients appear to have known the oxide of antimony, to which they gave the name of *στιμμι, stibium*. Pliny speaks of it, and says the oxide was used as a remedy for sore eyes. He not only describes the compound, but gives a method of preparing the mineral balsam. The sulphide of antimony, called the *regulus of antimony*, was likewise known to the ancients; but it was not until the fifteenth century that the metal was extracted from the ore by Basil Valentine and called antimony. The learned monk gives the following process of reduction: "Take of the best *Hungarian antimony* [meaning the sulphide] and crude tartar [*i.e.*, cream of tartar or crust of wine] equal parts, and of salt nitre half a part; grind them well together, and afterwards flux them in a wind furnace; pour out the flowing matter into a cone, and then let it cool; then you will find the *regulus;* which thrice, or oftener, purge by fire with tartar and nitre, and it will be bright and white, shining like *cupellate silver*, which hath fulminated [alluding to the brightening up of the silver on the cupel when the process is complete] and overcome all its lead." We have only to complete this process with the method of purification recommended by Dr. Thomson—viz., pounding the crude metal, mixing it with its own weight of antimonic acid, and fusing in a crucible, and the antimony is obtained in a state of purity. Native antimony, containing about 98 per cent. of the metal, is found in the gneiss mountains of Chalanches in Dauphiny in France.

White antimony ore, red ore, or oxide of antimony, is likewise found in moderate quantities in Bohemia, Saxony, and Hungary; but the most important ore containing this metal is the "radiated grey antimony" ore, the tersulphide of antimony (SbS_3), consisting of 72·8 antimony and 27·2 sulphur. It occurs in Scotland, Cornwall, Norway, Saxony, Bohemia, Hungary; and hence the title given to it by Basil Valentine of *Hungarian antimony*. The reduction of this metal from the ore is conducted, on the large scale, with a reverberatory furnace provided with a sloping hearth; the heat fuses the tersulphide, which flows away from the earthy matters, to the lower part of the hearth into proper vessels placed to receive it. The tersulphide is then roasted, converted into an oxysulphide, or glass of antimony, and finally reduced with charcoal and carbonate of soda.

One of the best modes of assaying the sulphide is to fuse it with cyanide of potassium, by Mitchell's method, in which he employs one part ore and four of cyanide of potassium; the heat required is so very low that little, if any antimony, is lost by sublimation. Antimony, when pure, has a silver-white colour and much brilliancy. Basil Valentine, whilst

* Worcester, in his new "Dictionary," says that *αντι, against*, and *μονος, one* or *alone*, mean, when combined as in antimony, a metal seldom found alone. *See* p. 152 (table).

describing the reduction of the ore to the metallic state, says, "You will obtain a fair star, (*) bright and shining like cupellate silver."

Antimony is partly fibrous, or rather made up of a number of very fine plates; it crystallizes in the octohedral form, and being very brittle, is easily reduced to powder. The specific gravity of antimony is 6·702, and it melts at about 800° Fahrenheit, and although it does not volatilize so readily as zinc, still it assumes the state of vapour at high temperatures.

Experiments with Antimony.

First Series.

A globule of melted antimony thrown down from a height of about two feet on to the centre of a levelled sheet of cartridge paper, exhibits the most eccentric movements, dividing itself into numberless minute beads, which bound and rebound over the surface of the paper, leaving a track of oxide, and burning at the same time with considerable brilliancy. Mr. G. Gore, the talented electro-metallurgist of Birmingham, has discovered that there are peculiar modifications of metallic antimony obtainable by electro-deposit, which he terms *amorphous* and *crystalline*, *dark* and *grey*. For the special production of the dark amorphous antimony, he employs a solution composed of the ordinary chloride of antimony saturated with tartar emetic, using about three or four parts of the former to one of the latter; and for the precipitate of the crystalline grey antimony, a solution is made of five parts tartar emetic, five parts tartaric acid, dissolved in a mixture of ten parts of hydrochloric acid and thirty parts of water, each solution being filtered before using.

To prepare Gore's amorphous antimony, take any quantity, say, for the sake of convenience, ten ounces by measure (*i.e.*, half a pint) of pure hydrochloric acid; add to it as much as it will dissolve of oxide of antimony (this will be about two and a half or three ounces by weight, if the acid is of the usual strength), and then add about five or six ounces more of the pure acid, and well stir the mixture. Pulverized tartar emetic may be substituted for the oxide of antimony with but little disadvantage. Prepare a small voltaic battery of about two pairs of plates; connect a piece of the purest commercial quality of antimony (known as "best French regulus") with the positive pole of the battery, and suspend it in the solution, so that the connecting wire is not in contact with the liquid, and connect a polished and clean sheet of thin sheet silver or copper with the negative pole of the battery, and immerse it also vertically in the liquid at about two or three inches distance from the antimony, taking care to have about as large a surface of silver or copper in contact with the liquid as of antimony. The sheet of metal will immediately acquire a nearly black shining coating of "amorphous antimony," which goes on increasing in thickness as long as the power of the battery continues. The process should be continued until the coating is about one-twelfth or one-sixteenth of an inch thick on each side of the sheet; this will occupy about three days and nights,

if the battery is moderately strong. The solution should be stirred with a rod of gutta-percha or glass every morning and evening during the action.

When the deposit is sufficiently thick, transfer the coated sheet to a *wooden* bowl into which a stream of *cold* water is freely running, and clean the metal (which will become covered with a white powder) by means of a soft brush; bend the sheet of metal *very slowly* and cautiously under the surface of the water, the "amorphous antimony" will then fall off in large plates, which should be at once removed and broken upon a surface of *wood*, under *cold* water, into fragments of the desired size, by a gentle blow with the end of a *wooden* rod; the fragments should then be wiped dry and placed at short distances asunder upon a narrow strip of cotton wool, which may then be formed into a roll and kept for many months, and conveyed with safety.

The peculiar property of this substance is, that it evolves a large amount of heat by slight causes, such as friction, a blow, momentary contact of a heated wire, a flame, &c.; and that the heat evolved is not due to cohesive action, nor to alteration of the specific heat of the substance. The temperature at which the sudden discharge occurs varies from 170° to upwards of 212° Fah. The total amount of heat evolved by electro-deposited antimony is usually sufficient to raise the temperature of an equal weight of ordinary antimony about 650° Fah. The evolution of the vapour of terchloride of antimony is not a *cause*, but an *effect* of the heat. The active substance consists of about 93·5 per cent. of antimony, 6·0 per cent. of terchloride of antimony, 0·3 per cent. of hydrochloric acid, and a trace of water. It is also liable to contain traces of nearly all the impurities of the anode and of the depositing liquid. The discharge of heat is always attended by a diminution of attraction between the metal and its associated terchloride of antimony. The terchloride of antimony cannot apparently be extracted without destroying the heating property of the substance, and by lapse of time the active substance invariably loses its heating power, especially if it is in a state of mixed division.

Much amusement has on many occasions been produced at juvenile parties, soirées, &c., by taking a number of small fragments of the substance, about one-sixteenth or one-twelfth of an inch thick, and about three-eighths or half an inch square, handing them round in single pieces to persons with a request to hold it *very firmly* between the finger and thumb of the left hand, and rub it *quite hard* with the edge of a new sixpence or other rough and hard body; it then quickly evolves so much heat as to adhere rather strongly to the fingers, and much amusement is created by the violent movements exerted to get rid of it. If the substance is very cold, or if it has been prepared many months, it does not readily act; it should in that case be made warm and rubbed immediately. After a fragment has once evolved its heat it is valueless, as it does not evolve heat a second time. A mass of the substance of half an inch or three-eighths of an inch thick evolves sufficient heat to melt tin and other metals. The amount of heat evolved by one ounce of the

substance has been found by actual measurement to be sufficient to raise the temperature of one ounce of common antimony from 50° Fah. to 700° Fah., that is, 650°; but no flame or actual ignition of paper, cloth, wood, &c., is produced in any instance.

It has been exhibited by Dr. Tyndall before the Royal Society; and a full account of its properties is published in the Philosophical Transactions of that body for the year 1858.

The substance has not at present been applied to any useful or manufacturing purpose, although the cost of producing it upon a large scale would be comparatively small.

Second Series.

To produce the crystalline antimony, prepare some of the second liquid already described, and proceed in the same manner as for the production of the amorphous antimony, except that a much larger receiving surface should be used in consequence of the greater tendency to a sandy deposit. In this case the deposit is grey, and frequently of a dull aspect, or even a dark, loose, granular powder, if the power is too great; but when properly produced, it has a silky lustre or semi-iridescent silver-grey appearance, especially when viewed within the liquid; and if the process is continued for several days, or better, for one week, the edges of the deposit assume a partly nodular form. The cleaning of the anode in this case may be of less frequency and with water alone.

Antimony trees, consisting of branches of amorphous and crystalline nodules, are easily formed by suspending a horizontal copper wire as a cathode, upon the surface of the terchloride solution.

The fracture of amorphous antimony is conchoidal, smooth, and waxy; that of the grey variety is crystalline, radiating like hematite. The texture of the amorphous variety is rather soft and weak, that of the crystalline quite hard and strong; the former files easily, the latter with more difficulty.

Third Series.

The combining equivalent of antimony is 129, and it unites with oxygen in at least three proportions, viz.:—

1. The suboxide of antimony . . . Sb_3O_4.
2. The teroxide of antimony . . . . SbO_3.
3. Antimonic acid . . . . . SbO_5.

The first oxide constitutes what may be termed the rust of antimony, or the film which gradually forms on the surface of the brilliant metal. The second, the teroxide, is the important oxide which is contained in that valuable medicine called tartar emetic, the tartrate of antimony and potash, $KO,SbO_3,\overline{T}+Aq$. The teroxide is obtained by heating antimony at a tolerably high temperature in an open vessel, when it sublimes as a white vapour, which condenses, and collected constitutes a white oxide formerly called *argentine flowers of antimony*. Basil Valentine, speaking of its preparation, says: "Some have peculiar in-

struments for this work, prepared with windy caverns through which the antimony may receive the air, and be sublimed. . . . But the process by which I make the flowers of antimony most profitable for medicine is this: I mixed the red flowers of antimony with colcothar of vitriol—*i.e.*, red oxide of iron, and sublimed them together thrice." The next cut shows a convenient method of preparing the teroxide of antimony.

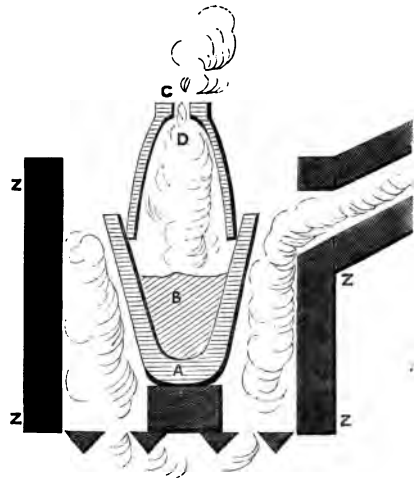


Fig. 226. Preparation of the Anhydrous Teroxide of Antimony. A. Lower crucible standing on a brick in the furnace z z z z, and containing the melted antimony B, which, being gradually oxidized, forms the teroxide; and this latter sublimes into the upper inverted crucible, with hole in bottom, C, and condenses at D in needle-shaped crystals.

Antimonic acid is obtained by dissolving antimony in aqua regia, evaporating the solution to dryness, adding nitric acid to the residue, and heating it till all the nitric acid is expelled; it combines with potash, soda, ammonia, and also with the teroxide of antimony. "James's powder," identical with pulvis antimonialis, is a mixture of fifty-seven parts of impure teroxide of antimony and forty-three of phosphate of lime.

Fourth Series.

Chlorine, iodine, bromine, and fluorine all unite with antimony. Of these combinations the most interesting is, perhaps, that peculiar fatty greyish-white product obtained by distilling a mixture of two parts corrosive sublimate and one of powdered antimony. This substance was formerly called the "butter of antimony," and is a terchloride of the metal.

Finely-powdered antimony dropped into a bottle of dry chlorine takes fire and produces the same product.

Fifth Series.

Hydrogen unites with antimony most probably in the ratio of the formula SbH_3. Antimoniuretted hydrogen is produced by pouring a solution of antimony into a vessel containing the usual materials for generating hydrogen gas—viz., granulated zinc and pure dilute sulphuric acid; the gas burns with a peculiar coloured flame, and if a white porcelain dish or piece of window glass is held above it, a bright metallic stain of antimony is deposited which may be mistaken for arsenic, but is easily distinguished by adding some strong nitric acid, and evaporating to dryness; on the addition of a little distilled water and a drop or two of a solution of nitrate of silver, a dirty-white precipitate is obtained, perfectly different from the brick-red one obtained when the arsenic stain is treated in a similar manner. Moreover, the antimony stain is insoluble in a solution of chloride of lime, which readily dissolves the arsenic mirror or stain.

Sixth Series.

The tests for the metal antimony afford the most unmistakeable results.

Sulphuretted hydrogen precipitates from solutions of the teroxide, such as tartar emetic, an orange-red precipitate of the hydrated tersulphide of antimony, SbS_3HO, both in acid and neutral solutions. If the solution is very dilute and neutral, it merely changes to a red colour, but the precipitate falls on the addition of some hydrochloric acid. Potash, soda, and ammonia throw down bulky white precipitates of the hydrated teroxide of antimony soluble in an excess of the reagents.

Tincture of galls affords a white precipitate with solutions of antimony.

The tersulphide of antimony dissolves in boiling hydrochloric acid, with the evolution of sulphuretted hydrogen; and if the solution is poured into a large test glass containing distilled water, a dense white precipitate is formed of the oxychloride of antimony, called the "*powder of algaroth*," $SbCl_3,2\,SbO_3HO$, soluble in tartaric acid.

Seventh Series.

The alloys of antimony are very important, and amongst them may be noticed "*Britannia metal*," composed of 100 parts of tin, 8 of antimony, 2 of bismuth, and 2 of copper; but the special alloy of this metal is, with lead, called "type metal," and composed of 4 parts of lead and 1 of antimony. Its hardness is such as to resist without breaking and bending the sudden pressure of the printing press. It

would be impossible to state briefly the wonderful agency of this human invention, which is gradually spreading knowledge in all languages to nearly every nation and people of the earth. The daily and weekly "press" of the United Kingdom, taken as a single example of the work of the "printing press," exhibits an irresistible power which is the marvel and praise of the whole civilized world.

Fig. 227. *Times* Printing Office, Publishing Hour.

Fig. 228. The Trial of Madame Laffarge.

CHAPTER XIII.

ARSENIC.

If the old alchemists had been aware that this metal would have been made the instrument of so many crimes amongst high and low of all degrees, they would probably have represented it by the sign of the "death's head and cross bones." Arsenic, like alcohol, is one of the good things which were created for man's use and profit, but it has been fearfully and wickedly abused.

The learned Dr. Thomson states that the word *arsenic* (*αρσενικον*, powerful) occurs first in the works of Dioscorides, and some other authors who wrote about the beginning of the Christian era. It denotes in their works the same substance which Aristotle had called *σανδαραχη*, and his disciple, Theophrastus, *αρρενικον*, which is a reddish-coloured mineral, composed of arsenic and sulphur, used by the ancients in

painting, and as a medicine. The *white oxide of arsenic*, or what is known in commerce by the name of arsenic, is mentioned by Avicenna, in the eleventh century; but at what period the metal called arsenic was first extracted from that oxide is unknown. Paracelsus seems to have known it, but the metal does not appear to have been obtained as a simple or single body until Brandt, in 1733, described an accurate process for procuring it.

Arsenic occurs as a metal and mineralized in nature, and the following minerals are well known:—

Name.	Composition.
Native arsenic	Arsenic.
Oxide of arsenic . . .	Oxygen and arsenic.
Red orpiment, or realgar, Yellow orpiment . . .	Sulphur and arsenic.
Common arsenical pyrites	Arsenic, sulphur, iron.
Pharmacolite	Arsenic acid, lime, water, with sometimes magnesia and oxide of cobalt.

The oxide of arsenic, or arsenious acid, is obtained as a secondary product from the roasting of certain minerals, such as arsenical pyrites, cobalt, tin, copper and lead ores. They are placed on the hearth or sole of a reverberatory furnace, to which an abundance of heated air (coming through the grate) is admitted. The oxygen of the air combines with the sulphur of the mineral, and forms sulphurous acid gas, which flies up the chimney, and is thus wasted and lost; whilst the combination of arsenic and oxygen—viz., arsenious acid—condenses in cells, chambers, or flues through which the air from the reverberatory furnace must pass before it finally escapes into the atmosphere. The crude white arsenic is then re-sublimed, not in expensive glass vessels or alembics, but in cast-iron tubes or retorts fitted to wrought-iron receivers. The author has seen masses of re-sublimed white arsenic which have appeared more like porcelain than arsenious acid; and, indeed, this substance is employed to impart the appearance of porcelain to glass. The metal arsenic can be procured by heating the oxide with black flux, and when deposited on the inner surface of a glass tube, presents a most perfect brilliancy called the "arsenic mirror," to which special allusion will be made in the experiments with this metal. Arsenic has a steel-grey colour, is extremely brittle, and when carefully sublimed, assumes a very perfect crystalline form—viz., that of brilliant rhombohedral crystals. The specific gravity of arsenic is 5·75. One of the most important uses of the metal is for the purpose of conferring a perfect spherical figure to the melted lead as it falls through the colander placed at the summit of the lofty shot towers which rear their heads in the neighbourhood of Waterloo Bridge and elsewhere. If too much arsenic is added, the shots have a double-convex form, but are not spherical; and when too small a quantity has been alloyed with the lead, the drops are pear-

shaped, and some practice is required to adjust the precise quantity of arsenic, which not only confers a spherical figure, but likewise hardens the lead considerably. Arsenic is likewise used to whiten copper, and small quantities are employed in casting the specula for telescopes.

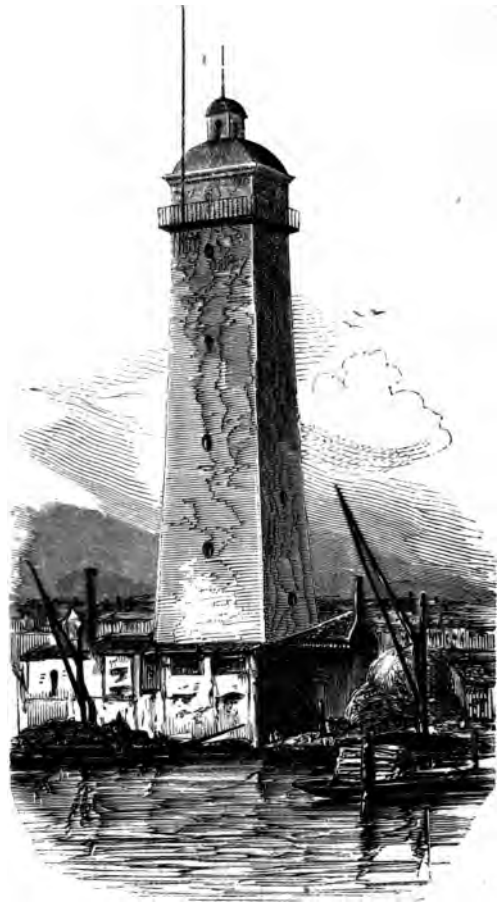


Fig. 229. Shot-Tower, near Waterloo Bridge.

Experiments with Arsenic.

First Series.

The combining equivalent of arsenic is 75, and it unites with oxygen in two proportions, forming—

Arsenious acid, or white arsenic . . . . . AsO_3.
Arsenic acid . . . . . AsO_5.

White arsenic is readily prepared from metallic arsenic, by subliming a small quantity of the metal through a glass tube open at both ends. After chasing it about slowly with the flame of a spirit lamp, it is converted into perfect octohedra (like alum) of arsenious acid.

Arsenious acid is readily converted into arsenic acid by digesting it with nitric acid mixed with a small quantity of hydrochloric acid, and evaporating to dryness, and heating till all the excess of acid is driven off.

Second Series.

Powdered metallic arsenic, brought in contact with chlorine gas, by sprinkling it into a bottle containing that element, takes fire, and produces a chloride of arsenic. A definite terchloride ($AsCl_3$) is prepared by distilling arsenic with corrosive sublimate; but very great caution must be used in experiments with this metal, to avoid inhaling any of the fumes from these preparations.

Third Series.

Sulphur forms no less than five compounds with arsenic, of which the most remarkable are realgar, or red orpiment (AsS_2); a bisulphide of arsenic; and yellow orpiment, or king's yellow, a tersulphide of arsenic (AsS_3). The latter is easily made, either by distilling white arsenic with sulphur, or by precipitating a solution of arsenious acid with sulphuretted hydrogen, with the addition of a little hydrochloric acid. This hydrated tersulphide is soluble in nitric acid and ammonia. Before the exposures which took place under the supervision of Dr. Hassall and the Sanitary Commission of "The Lancet," great carelessness was observable in the colouring of twelfth-cake ornaments and other things which might come into the hands of children; and there can be no doubt that the preparations of arsenic have performed their fatal mission, in times now happily gone by, and many a child has probably been hurried into eternity by some of the vile trash called "sweets" coloured with poisonous metallic preparations to make them more attractive. Orpiment especially was a favourite colouring material, equalled, if not surpassed, in popularity by the lovely green produced by precipitating a solution of sulphate of copper with one of arsenious acid, to which carbonate of potash has been added. This colour is called "Scheele's green," and is an arsenite of copper, consisting of two equivalents of oxide of copper united to one of arsenious acid. It

is also prepared by adding a solution of the ammonio-sulphate of copper to one of arsenious acid.

Fourth Series.

There is unhappily no metal whose reactions with other bodies have been so carefully studied as those of arsenic, or rather white arsenic, that being the poison supposed to have been used by the infamous Tophania or Toffana, who resided first at Palermo, and afterwards at Naples; this wretch, who was put to the rack, and afterwards strangled, confessed to having caused the death of not less than six hundred persons. This disgrace to her sex was succeeded, as arsenical poisoner-in-chief, by another woman, if anything, even more infamous and satanic, the Marchioness de Brinvilliers, who was at last condemned and executed at Paris, being first beheaded and then burnt, on the 16th of July, 1676.

In the nineteenth century the succession of the evil name of arsenical poisoner passed, by universal consent and execration, to Madame Laffarge, who managed to escape death by the *sentiment* she artfully provoked in her judges and the public, but who was reserved, perhaps, for worse than death—viz., the slow but sure action of conscience and the stern, unrelenting discipline of a French criminal prison. Great numbers of male arsenical poisoners have equalled, if not surpassed, in individual acts of deep-laid villany, the accumulated tragedies of a Toffana or a Brinvilliers; but it is strange that in the early days of these dark deeds that women should have gained such an unenviable notoriety in that respect. It seems that we do not now require professional poison-makers, as arsenic is brought within the reach of any one, and Mr. Draper has found an average of 2·55 grains of arsenic (quite enough to destroy life) in each of the papier-Moure fly-papers. Hence they might lead to the accidental poisoning of children, or serve the purpose of criminals.

Marsh's Test is a most convenient preliminary one, on account of its being so easily and quickly applied; but it is not absolutely relied on, because antimony affords the same kind of result, and where the two poisons may exist together, neither could be detected with certainty; its value consists in proving at once the presence or absence of arsenic or antimony. It may be arranged in an expeditious manner, by passing a tobacco-pipe through a cork fitted into a perfectly clean bottle containing some zinc and dilute sulphuric acid, both of which it is, perhaps, needless to state, must be free from arsenic. When the hydrogen is being freely evolved, a little of the fluid suspected to contain arsenic may first be boiled in a test tube, to coagulate any matters which are affected by a temperature of 212°, and then poured into the bottle containing the zinc and acid. The escaping hydrogen is now set on fire, and a piece of white hard porcelain or a clean white plate held close over the end of the tobacco-pipe, so as to cut the flame in half; if any arsenic or antimony are present, they are deposited on the porcelain as a dark, metallic, and shining mirror, which, when once seen, is unmistakeable. A little nitric

acid is now dropped on the stain, and the porcelain heated, and the plate is put into the oven; when the excess of acid is evaporated, a few drops of water are added, and the solution tested with one of nitrate of silver, with (if required) a few drops of dilute ammonia, when a brick-red precipitate of arseniate of silver, soluble in nitric acid and ammonia, is obtained. If the stain be antimony, the precipitate with nitrate of silver is a dirty-white, quite different from that of arsenic. When the hydrogen is burning, a number of stains or "mirrors" may be taken on separate bits of glass or porcelain, or on different parts of the plate; and if a beaker glass is held above the burning gas, containing the arseniuretted hydrogen, the arsenic is oxidized and converted into white arsenic, which deposits in the glass, and, being dissolved with boiling distilled water, will afford a yellow precipitate of arsenite of silver with Hume's test (viz., the ammonio-nitrate of silver, which must be free from excess of ammonia), or Scheele's green with neutral solution of ammonio-sulphate of copper. Both of these tests are best applied by first adding either the solution of silver or copper separately, and then taking a stirring rod moistened with ammonia, and holding it at the top, and just touching the solution supposed to contain the white arsenic, when the precipitate of yellow arsenite of silver or green arsenite of copper falls in a very distinct manner. There are more refined methods of applying Marsh's test; but, as the youthful readers of this book are not likely to be engaged in medico-legal inquiries, enough has been said to enable the experimentalist to detect arsenic in a mineral, which of course must first be dissolved in an acid.

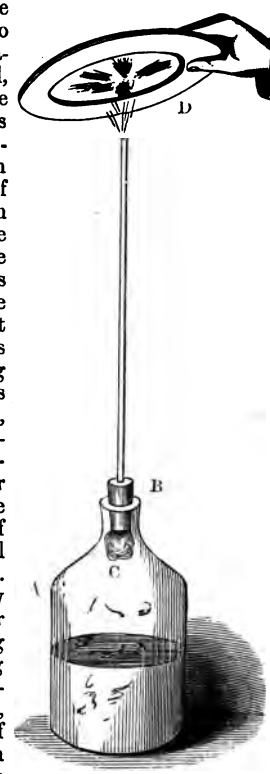


Fig. 230. Marsh's Test. A. Bottle containing zinc and dilute sulphuric acid and the suspected fluid. B. Cork and tube, or clean tobacco-pipe fitted through cork, and having some clean, dry cotton-wool, C, lightly tied at the bottom of the cork, to stop the moisture which condenses in the pipe and spoils the experiment. D. Plate covered with black stains of arsenic; in one or two seconds an arsenic mirror is obtained, and if the plate is held over the flame for a longer time, the indication may be lost.

Reinsch's test is the one now preferred by toxicologists, and consists in the use of copper wire-gauze rendered chemically clean by dipping it into strong nitric acid and washing thoroughly with water. The suspected fluid is rendered acid by hydrochloric acid,—if nitric and chloric

acids (chlorate of potash, for instance) are present, they should first be got rid of—and then boiled for ten minutes with the clean copper gauze. If a film deposits, the gauze should be withdrawn, and another piece put in, as any number of pieces of wire gauze can be kept clean and ready for use by attaching them to a suspending thin copper wire, dipping them in nitric acid, washing, and leaving the gauze under pure water. The gauze taken out of the liquid under examination is now well washed with water and carefully dried, it is then placed in a clean, hard German glass tube of a small diameter, certainly not wider than two-eighths of an inch, and the heat of a spirit lamp gradually applied to the place where the wire gauze is resting, and the tube slightly inclined upwards. By this manipulation a current of air oxidizes the metallic arsenic as it is sublimed from the surface of the gauze, and forms white arsenic, which condenses in the further end of the tube, and may be washed out afterwards with boiling water and tested by the reagents already named.

The following remarks on arsenic sublimates, made by Frederick W. Griffin, Ph.D., of Bristol, are so important, that we give them entire:—

"While acknowledging the ingenious character of many of Dr. Guy's adaptations, as described in his paper read before the Society of Arts, I must altogether demur to the proposed employment of flat discs of glass for receiving arsenical crusts. Except with very high magnifying powers (which are rendered unnecessary by adopting a process which I shall presently describe), a glass tube of half an inch diameter offers equal facilities for examination under the microscope. Indeed, for small crystals, even a quarter-inch objective (magnifying 500 diameters) can be so employed, with the slight drawback of needing some extra focusing. On the other hand, the rapid sublimation required in Dr. Guy's method must involve the loss of part of the arsenical vapour at the mouth of the tube, which is only loosely covered by the flat glass; and another portion, being very dense, will remain in the tube itself, whilst that which reaches the disc will be deposited on it in a nearly amorphous condition. No wonder that such 'mists' should frequently require objectives of one-eighth inch to develope any crystallic character, and even then a few imperfect triangular facets afford but unsatisfactory evidence of *octohedralism* when we consider what weighty issues are in a measure dependent on the making out that feature. It is, however, in the power of the operator to obtain crystals of arsenious acid as perfect as he can those of alum an inch or two in diameter, and by acting on the same principle, namely, by obtaining a very gradual formation during slow cooling. The following is the *modus operandi*, as described in Table I. of my 'Compendium of Qualitative Analysis.' Drive the substance entirely off the lower half of the tube, which is made very hot by waving it about in the flame. Then revaporize the sublimate, holding the tube (which should be closed by a loosely-fitting cork) as upright as possible. The dense vapour sinks to the bottom, and will give large and regular crystals as the glass slowly cools. These crystals glitter in the sun like diamonds, and exhibit the same play of colours: they are from

$\frac{1}{150}$th to $\frac{1}{100}$th of an inch in diameter, and under an inch objective form splendid specimens for the micro-crystallographer. Here and there we find octohedra absolutely perfect, but they are more frequently truncated; all the angles, however, being beautifully sharp. The majority are transparent, but some are only translucent, or even opaque. By reflected light (using a bull's-eye condenser) they appear, in consequence of their adamantine lustre, like diamonds lying in high relief on a black ground; but their complete shape is most strikingly displayed by a combination of strong reflected and feebler transmitted rays of various degrees of obliquity. A tube of half an inch diameter, under a one-inch objective, presents nearly the entire field in focus, and the perfect crystals appear from one-half to three-quarters of an inch in diameter.

"As regards the statement that arsenious acid sometimes assumes the cubic form, I would venture to suggest that Dr. Guy may possibly have been deceived by a hasty examination. An octohedron, if opaque and seen only by transmitted light, often appears a cube, since, when viewed perpendicularly to either axis, its section or outline is square. I may mention as a parallel case, that I have obtained crystals of hydrate of chlorine full a tenth of an inch in diameter, which, for the most part, seemed to be perfect rhombs (the angles were 110° and 70°), but closer observation convinced me that Faraday's description of them as 'acute flattened octohedra with three unequal axes' (*i.e.* rhombic octohedra) was really correct. Such misapprehensions are very likely to occur under high magnifying powers.

"I will describe an actual experiment which will show that my method is as applicable to minute quantities as Dr. Guy's, while it is far more conclusive in its results. Dr. Guy states that $\frac{1}{1000}$th of a grain of arsenious acid yielded on sublimation a 'circular mist consisting of brilliant detached points distributed evenly over the surface (of a disc), and easily resolved into octohedra under *an eighth* power of the microscope.' By way of comparison, I accurately weighed out a grain of pure arsenious acid on a balance sensible to the thousandth of a grain. I dissolved this in water, and made up to a known bulk. By means of a graduated pipette I took a thousanth part of this, containing, of course, a thousandth part of a grain of arsenious acid, and evaporated it to dryness on a bit of curved glass. The latter, with the slight residue adhering to it, was then cut up and placed in a corked tube four inches long by four-tenths of an inch in diameter. On igniting the fragments, a feeble sublimate appeared half way up the tube, which, under a quarter-inch objective, was seen to consist of granules, evidently crystalline, but of indeterminable shape, and not more than $\frac{1}{10000}$th of an inch in size. Resublimed by my method, these gave a few octohedra, which were sought out by the inch objective, and then examined under the quarter-inch. They were beautifully perfect in shape, and about $\frac{1}{1200}$th of an inch in diameter. This alone would yield the strongest presumptive evidence of the nature of the substance in question, but I can by no means agree with one of the speakers at the meeting (Dr. Thudichum), who considered that we might afford to neglect applying the liquid tests

to a solution of the sublimate. Each reaction must stand for what it is worth, but the concurrence of many furnishes proof the most irrefragible. The above quantity seems to be about the smallest that would yield any definite result in a tube of the size named; but unless much more than a thousandth of a grain of arsenious acid were obtained by Reinsch's tests, I, for one, should be extremely loth to assert that it had been criminally administered. Indeed, I fear that the detection of this particular poison has reached an almost dangerous degree of delicacy, for we live surrounded by means of unconsciously absorbing traces of arsenic. We breathe arsenicated dust from the green flock papers on our walls; arsenical *papier-Moure* lies soaking on dishes afterwards used for culinary purpose; arsenic is contained in glazed green papers which are often employed for wrapping cocoa and other articles of food, and confectioners supply it wholesale in their cake-ornaments. The very drugs prescribed for our relief, especially the compounds of bismuth, are tainted with arsenic, and it has even been detected in carbonate of soda. Nay, more, our vegetable food, as Professor Davy has lately pointed out, may be contaminated with arsenic derived from superphosphate-manure, and there is probably no drinking-water containing iron without a trace of arsenic as well. Now, metals are remarkably prone to become localized in particular organs; the 'dropped joints' of painters are found to contain lead permanently combined with the tissue; and a course of iodide of potassium will bring off abundance of mercury by the urine, years after its administration. It would appear by no means improbable that traces of arsenic occasionally introduced into the system, may be stored up in like manner (especially in the liver), till, in the course of years, the amount becomes appreciable. Many aquatic plants contain much iodine, all gradually absorbed from the water in which they live, though it cannot be detected therein, from the minuteness of its quantity; the vegetable tissue, however, accumulates it and retains it persistently. So may it be with arsenic in the human body; and I think toxicologists should pause before affirming that it had been criminally administered, unless a proportionate amount of the poison is found."

Sulphuretted hydrogen throws down orpiment in solutions of white arsenic, provided a few drops of hydrochloric acid are added, and this, taken in conjunction with the nitrate of silver test, is greatly to be relied on.

Before dismissing the subject of white arsenic, it may be stated that it is employed for very many useful purposes—viz., in the manufacture of glass and enamel, and also for destroying vermin, and for other purposes in the treatment of sheep.

The strangest story in connexion with this poison is the fact attested by the most truthful evidence, obtained by Mr. Heisch, the eminent Professor of Chemistry at the Middlesex Hospital School—viz., that the peasants and other persons in Germany, and especially in the metallurgical districts of Styria, actually eat small doses of white arsenic to improve their personal appearance, and also to increase their powers of sus-

taining fatigue in the ascent of this romantic Alpine region. Amongst the evidence adduced are the following statements: "There is in Stürzburg a well-known arsenic eater, Mr. Schmid, who now takes daily twelve and sometimes fifteen grains of arsenic. He began taking arsenic from *curiosity*, and appears very healthy, but always becomes sickly and falls away if he attempts to leave it off." They say, "In this part of the world, when a graveyard is full, it is shut up for about twelve years, when all the graves which are not private property are purchased and dug up, the bones collected in the charnel-house, the ground ploughed over, and burying begins again. On these occasions the bodies of arsenic-eaters are found almost unchanged and recognisable by their friends." Many people suppose that the finding of their bodies is the origin of the story of the "Vampire."

Fig. 231. Arsenic-eaters of Styria.

Fig. 232. Use of Nitrate of Baryta, mixed with Sulphur and Charcoal, for the Green Fire of the Ghost Scene.

CHAPTER XIV.

BARIUM.

Amongst the host of new metals with which Sir H. Davy surprised the scientific world at the beginning of the nineteenth century was the metal barium, so called from the Greek βαρὺς, heavy, because of its existence in a very common mineral that occurs in veins, and rocks of all ages, called "heavy spar," consisting of sulphuric acid and the oxide of barium or baryta, and termed sulphate of baryta. This mineral is used extensively for the purpose of mixing with white lead; we must not, perhaps, call it adulteration at a certain commercial stage, because the wholesale people know perfectly well what they are about when they

buy white lead mixed with ground heavy spar, or still better, with heavy white, which is the same substance prepared artificially, and, therefore, much whiter and freer from earthy matter or oxide of iron, which imparts a yellow tinge to the pigment. The adulteration is only felt by Paterfamilias, who, innocently thinking to do a little economical painting (house) on his own account, buys some white lead, and is much disgusted to find that it soon washes off again, after a few vigorous applications of the domestic soap and water; moreover, a larger quantity of the adulterated than the pure white lead is required to cover a given surface properly. Analysis reveals all these delinquencies, and in the Government dockyards and arsenals white lead is not purchased until an analysis of the sample has been made. The heavy white is usually made from the carbonate of baryta, called by mineralogists "witherite," and found in large quantities in Lancashire, Northumberland, and Cumberland, and used to destroy vermin. In the localities where the carbonate of baryta occurs, the poultry frequently and innocently commit suicide by swallowing the poisonous mineral in mistake for chalk, and, therefore, must be kept shut up, at least from all access to the public roads along which cartloads of the mineral are conveyed.

The metal can be obtained by Davy's original process—viz., electrolizing carbonate of baryta in conjunction with mercury by a very powerful voltaic battery; the metal is eliminated in small quantities and amalgamates with the mercury; by subsequent distillation the latter is driven off, and the barium remains in the tube or retort. It is, however, more expeditiously obtained by subjecting baryta, on dense gas graphite charcoal, to the action of the oxy-hydrogen jet in which an excess of hydrogen is maintained.

After our experience of the actual properties of aluminium as compared with book statements, it is not surprising to find Dr. Matthiessen assert that barium powder has a yellow colour, decomposes water at ordinary temperatures, and oxidizes quickly when exposed to the atmosphere; whereas other authors assert that it is white, brilliant, and malleable.

Experiments with Barium.

First Series.

The equivalent of barium is 68·5, and it unites with oxygen in two proportions—viz.:—

Baryta	BaO
Binoxide of barium	BaO_2

Baryta is made by calcining the nitrate of baryta in a covered and capacious iron crucible, at a full red heat, until no more fumes escape. It is a grey cellular mass, and must be kept from contact with the air, as it soon "slacks" like lime, and, combining with water, changes to a white dust or hydrate of baryta. When water is dropped upon it, enough heat is evolved to fire gun cotton or phosphorus.

Barium, placed in water, decomposes the latter, unites with its oxygen, and forms baryta, which is dissolved, whilst the hydrogen escapes with effervescence. A solution of baryta in water is used as a test, and called *baryta water;* it must be kept in a well-closed bottle, as it possesses a remarkable affinity for carbonic acid. The carbonate of baryta dissolved in dilute nitric acid, forms nitrate of baryta, being the salt which is used so effectively in pyrotechnic compositions and at theatres to produce the livid colour on the "ghost;" the effect is, no doubt, very startling, unless an officious current of air should waft a strong draught of sulphurous acid (the supposed diet of such unfortunates) from the burning "green fire," and make the poor ghost *sneeze*.

The binoxide of barium is made by passing oxygen over baryta heated to a dull red heat, and Boussingault has indicated this substance to be a steady source of oxygen gas, as it can be made to absorb and deliver up its oxygen with the assistance of steam. The process deserves more attention than has hitherto been paid to it, because the oxygen so procured is taken from the air, and the only cost is for the baryta; there are, however, certain difficulties of manipulation, which render the process uncertain in the hands of ordinary work-people.

Second Series.

M. Thenard's method of preparing the pure peroxide of barium is as follows: "First make a pure nitrate of baryta, and give it a strong heat in a porcelain vessel, by which baryta, not quite pure, but containing traces of silica and alumina, but no manganese, will be obtained; the latter impurity must always be most cautiously avoided, for oxide of manganese possesses the property of energetically decomposing the oxygenated water. The baryta, broken into small pieces, is then introduced into a luted glass tube (the glass should not contain lead) large enough to contain about two pounds of it, and being heated to dull redness, a current of dry and perfectly pure oxygen gas is passed through, which it rapidly absorbs; this operation is to be continued till the oxygen escapes from a small tube inserted into the opposite extremity of the larger one. The peroxide of barium thus obtained is pale grey, and frequently some pieces are speckled with green, which announces the presence of manganese, and these portions should be rejected; its distinctive character is that it crumbles when a few drops of water are added to it, without producing heat."

It is from this substance that the so-called peroxide of hydrogen, or oxygenated water (HO_2), is obtained, which is colourless and inodorous. It blisters the cuticle of the tongue, and has a peculiar metallic taste. It is decomposed by all metals except iron, tin, antimony, and tellurium; the metals should be finely divided or in powder; silver and oxide of silver decompose it very suddenly with the evolution of heat and light; platinum and gold produce the same phenomena; lead and mercury slowly separate the oxygen. Orpiment and powdered sulphuret of molybdenum act upon it with the same violence as silver; the peroxides of manganese and of lead also occasion its instant decomposition.

A solution of nitrate of baryta, or one of the chloride of barium, is *the* test for sulphuric acid, with which it forms an insoluble white precipitate, already alluded to as sulphate of baryta.

The famous "phosphorescent Bolognese stone" is made from a radiated variety of heavy spar found near Bologna. The process consists in heating the mineral in conjunction with carbonaceous matter; most likely it is saturated with mucilage of gum arabic, or, perhaps, pure olive oil, and then calcined, and if exposed to the sun and afterwards brought into a darkened room, it emits a faint glow of light.

Fig. 233. The Bolognese Phosphorus.

Fig. 234. Lady at her Toilette applying the "Pearl-white" with a Hare's-foot.

CHAPTER XV.

BISMUTH.

When God's image is defaced with a mineral and poisonous powder, it must of course be for some special purpose; now, the savage tribes chiefly wear paint when they go to battle, to frighten their enemies, and hence the term "war paint," used by modern writers to express this peculiar decoration worn by a few silly women, is perhaps one of the severest reproofs ever administered to that absurd and foolish practice. The metal bismuth, so called from the German *wiessmate*, or "blooming meadow," is the one selected for this office; not, of

course, in the metallic state, but combined with nitric acid and water, and called the trisnitrate of bismuth, or "flake white," Bi,O_3NO_5+HO. This metal occurs in the native and mineralized state in various parts of Europe, and also in Cumberland and Cornwall. The greater portion of the bismuth sold in commerce is obtained by melting the "native bismuth" with certain precautions.

The metal is very brilliant, crystalline, and brittle, and as it fuses at a very low temperature, 477° Fah., beautiful cubic crystals (Fig. 235) like steps may be obtained by allowing a crucible full to cool till a pellicle forms on the top. This is then pierced with two holes, out of one of which the remaining liquid metal is poured, and the other allows the air to enter as the metal is displaced.

The specific gravity of bismuth is 9·8, and its equivalent 213.

Experiments with Bismuth.

First Series.

Bismuthic acid, BiO_5, and teroxide of bismuth, BiO_3, are the scientific oxygen compounds of this metal. The former is only interesting to the chemist, but the latter is the oxide in combination with nitric acid already spoken of as "flake white," and obtained by dissolving bismuth in nitric acid, and pouring it into water; by subsequent washing, the desired cosmetic is obtained, and great care is required in making it to please the fastidious eyes of Vanity Fair.

Second Series.

Ignition is sometimes produced during the violent action that takes place when nitric acid is poured upon powdered bismuth. Nitrate of bismuth is readily prepared by dissolving as much of the metal as a mixture of two parts nitric acid and one of water will take up. The decomposition is extremely rapid, and nitric oxide gas escapes in large quantities. The solution affords, on careful evaporation, beautiful four-sided prismatic crystals, which are decomposed at a red heat and leave oxide of bismuth. A most amusing form of invisible ink is obtained by writing on paper with a solution of nitrate of bismuth; the letters do not become visible until the paper is dipped into water, when the pearl white or *blanc de fard*, or magistery of bismuth, is precipitated—thus forming a white sympathetic ink.

Third Series.

The fusible metal that melts when placed in boiling water consists of eight bismuth, five lead, and three tin, and some persons—of course wags—have even gone to the expense of having it made into spoons; and the surprise of any grave personage who uses such a base spoon to stir his or her tea, to see that usually solid article of plate melt away before their eyes, may be more readily conceived than described. Pewter and type-metal also contain bismuth.

Fourth Series.

Bismuth is detected by sulphuretted hydrogen, which throws down a black precipitate of tersulphide of bismuth, BiS_3, from solutions of that metal, which is insoluble in dilute acids, alkalies, alkaline sulphides, and cyanide of potassium, but decomposed by concentrated boiling nitric acid.

Chromate of potash throws down a yellow precipitate of chromate of bismuth; unlike chromate of lead, being insoluble in potash, but soluble in dilute nitric acid.

The most characteristic reaction is the effect of water on solutions of bismuth, which are precipitated as white basic salts insoluble in tartaric acid.

Fig. 235. Crystallized Bismuth.

CHAPTER XVI.

CADMIUM.

THIS metal was discovered in 1818 by Stromeyer, and is so called from "Καδμεια," being the ancient name for the mineral containing zinc, used in the manufacture of brass; and as cadmium is a sort of twin brother to zinc, and is usually associated with it in nature, the title of cadmium was selected for it.

Mr. Herapath, the eminent chemist of Bristol, was the first to point out that the yellowish-brown matter adhering to the brick vault placed over the furnace and pots in which the zinc is distilled from calamine, contained about ten per cent. of cadmium.

The sublimate gradually collected from the "brown blaze" of the zinc furnace may be dissolved in dilute sulphuric acid, and on placing the solution in a platinum cup, according to the elegant method of Dr. Wollaston, and holding a zinc plate therein, the cadmium is precipitated on the sides of the vessel, and adheres so firmly that it may be washed and afterwards dissolved out with acids. Cadmium is a white, or bluish-grey metal, having a specific gravity of 8·6; it is soft, malleable, and ductile, and admits of being highly polished. There is only one oxide of cadmium, CdO, and if in solution, the metal is rendered apparent by the rich yellow precipitate of sulphide of cadmium, CdS, when sulphuretted hydrogen or sulphide of ammonium are added; insoluble in alkalies and dilute acids, but decomposed by strong nitric acid; likewise insoluble in an excess of sulphide of ammonia, which distinguishes the precipitate from the same colour obtained under similar circumstances with antimony, arsenic, and tin, all of which as sulphides are soluble in an excess of the sulphide of ammonium. Potash and ammonia throw down white precipitates of hydrated oxide of cadmium, insoluble in the former but soluble in ammonia.

The useful arts have not as yet been benefited by cadmium, except, perhaps, in the preparation (as Dr. Percy states) of the finest and *most durable* yellow colour with which the artist is acquainted, and made from the sulphide of cadmium.

Fig. 236. Lime Kilns.

CHAPTER XVII.

CALCIUM.

All over the country, in the most picturesque forms and situations, are to be seen numberless kilns or rude furnaces in which the well-known substance lime is prepared by burning chalk or limestone, both of which are impure forms of carbonate of lime. The existence of the metal calcium in lime was satisfactorily proved by Davy, who employed the same process to procure it as that described for the metal barium. The impetus given by M. St. Clair Deville to the cheaper production of these metals of the earths and alkalies, by the employment of sodium, has induced MM. Bunsen and Matthiessen to prepare calcium in quantity, and thus fill in a void which is apparent in all works on the metals—viz., the absence of a correct description of the properties of calcium.

Experiments with Calcium.

First Series.

In a valuable paper by Dr. Matthiessen, "On the Preparation of the Metals of the Alkalies and Alkaline Earths by Electrolysis,"* that

* Quarterly Journal of the Chemical Society, vol. viii. p. 27.

gentleman gives the following description of the preparation and properties of calcium. "A mixture of two equivalents of chloride of calcium and one of chloride of strontium with a small quantity of chloride of ammonium, is fused in a small porcelain crucible, in which a carbon positive pole is placed, and a thin harpsichord wire, wound round a thicker one, dipping only under the surface of the melted salt, is connected with the zinc of the battery formed of six of Bunsen's elements, the current of which is allowed to pass through the mixture.

"In order to obtain the beads of calcium, which hang on to the fine wire, the negative pole must be withdrawn, about every two to three minutes, along with the thin crust that forms round it. The surest method, however, to obtain the metal (although in very small beads), is by placing a pointed iron wire merely so as to touch the surface of the liquid; the great heat evolved, owing to the resistance to the current, causes the reduced metal to fuse and drop off from the point of the iron wire, and the bead is recovered from the liquid by means of a small iron spatula.

"The properties of calcium are the following: it is a light yellow metal of the colour of gold alloyed with silver, and has a specific gravity of 1·5778; on a freshly-filed surface the lustre somewhat decreases the yellow colour, which becomes more apparent if the light be reflected several times from two surfaces of calcium; a thin film of oxide produces the same effect. The hardness approaches that of gold, being from two to three. It is particularly ductile, and may be cut, filed, and hammered out to plates having the thickness of the finest paper, a piece not larger than a mustard seed having been flattened to the size of ten to fifteen square millimètres, showing only a few cracks at the border.

"In dry air the metal retains its colour and lustre for a few days only, but in presence of moisture the whole mass is slowly oxidized. Heated on platinum foil over a spirit lamp, it burns at a red heat with an excessively bright flash, about equal in intensity to the voltaic arc. Calcium is only slowly acted upon by dry chlorine; but when heated, burns in that gas with a most brilliant light, as also in iodine, bromine, oxygen, sulphur, &c. With phosphorus it combines without ignition, forming phosphide of calcium. Heated mercury dissolves it to a white amalgam. Water is rapidly decomposed by the metal, with the evolution of great heat and hydrogen; diluted nitric, hydrochloric, and sulphuric acids cause a still more rapid decomposition; the first acid often causing ignition. Concentrated nitric acid, even when heated almost to boiling, does not attack the metal, the action not beginning till the liquid boils. From these experiments, it appears that the metal formerly stated to have been obtained by the reduction of chloride of calcium with the alkaline metals cannot be calcium, but was most probably a mixture of potassium or sodium with aluminium, silicon, &c."

Second Series.

The equivalent of calcium is 20, and it forms with oxygen the well-known white lime, CaO, and is also capable of uniting with another equivalent of oxygen to form the peroxide of calcium, CaO_2. The mode of burning limestone, in order to drive off the interstitial water and combined carbonic acid, is very simple: a lofty inverted conical furnace is constructed with a proper hearth, over which a rude arch of lumps of the limestone is constructed: below the arch, which has many apertures left for the upward passage of the fire, is arranged the fuel, and above it the smaller lumps of the chalk or limestone: the fire is lighted carefully, and gradually increased, in about seventy hours the process of burning is completed. Lime is a brittle and somewhat sonorous white earthy solid, having a specific gravity of 2·3; it is extremely infusible, and is the substance selected for ignition with the intense heat of the oxyhydrogen blowpipe to produce the beautiful white light required for the exhibition of dissolving views, called the "lime light." After being exposed for some time to the action of the heat, a hollow is scooped out in the ball by the volatilization of the lime. All round the point where the jet of the mixed gases impinges on the surface of the ball, the lime is most beautifully crystalized. One of the inconveniences of this light caused by the cracking of the lime has been in a great measure surmounted by Prosser, who causes a thick slab of lime to move upwards in a brass frame (instead of the ordinary rotation by clockwork. Many years ago, Mr. Frederick Gye, the proprietor of the Covent Garden Opera House, constructed and used a good-sized slab of lime ground flat on one surface, and worked by an eccentric, so as to avoid the trouble of replacing cracked lime balls, and also to prevent the sudden eclipse of the light when this takes place.

The application of the lime light has now, perhaps, reached its culminating point, having been used during a part of the time Parliament was sitting this year, to illuminate the new Westminster Bridge at night, in the most admirable manner. When water is added to fresh-burnt lime, it unites chemically with that substance and forms the hydrate of lime, CaO,HO; this combination takes place with the evolution of considerable heat, and is usually called "slaking," whilst the hydrate is distinguished from the caustic lime by the term of "slaked lime." When the latter is shaken with some cold water in a bottle provided with a cork or stopper, and then allowed to settle, the clear solution is called lime water, and is employed as an important test for carbonic acid; see "Boys' Playbook of Science," p. 154.

Lime water, like baryta water, powerfully reddens turmeric paper, and if a little sugar is mixed with the slaked lime, water dissolves a much larger quantity. The chief test for lime is oxalic acid in the form of oxalate of ammonia, which precipitates the white oxalate of lime, insoluble in acetic and oxalic acids. Sulphate of soda precipitates sulphate of lime, CaO,SO_3HO+Aq, from concentrated solutions of lime, soluble in a large proportion of water, and more so, on the addition of

acids. A little alcohol added to weak solutions of lime will assist the precipitation of the sulphate.

Third Series.

The number of minerals that are formed of lime salts may truly be called "legion."

Count Bournon has described seven hundred varieties of calc spar or carbonate of lime, of which the following well-known substances may be mentioned:—Marble of all kinds, oolite egg or roe-stone, pisolite, chalk, marl, tufa, double-refracting spar.

Fluor spar, or "blue John," so common in Derbyshire and elsewhere, is a fluoride of calcium. Phosphate of lime, the important chief earthy constituent of bone, takes a position as a manure which is not surpassed by any other metallic salt. The eminent practical and scientific agriculturist, Mr. Lawes, has clearly shown that phosphates are *the* manure for turnips and other root crops.

Gypsum, or sulphate of lime, is another common mineral, of which the transparent crystals are called selenite, and are used for objects in the polariscope; whilst the same mineral when calcined forms that truly valuable medium by which sculpture and other works of art are copied in the well-known substance termed "plaster of Paris."

Lime and its combinations are therefore amongst minerals almost what oxygen is in the non-metallic group of elements; and lime is used not only for mortar, cement, manure, tanning, soap-boiling, &c., but is employed in the state of carbonate for sculpture, architecture, and general ornamental stone-work, whitewashing, soda-water making, &c.; also in glass-making, and, as already shown, is the important flux for iron-stone.

Fourth Series.

Amongst the reagents that indicate the presence of lime in solution, may be mentioned the carbonates of the alkalies, which throw down white precipitates of $CaOCO_2$. In acid solutions, boiling assists the entire precipitation of the carbonate of lime, and the presence of ammoniacal salts do not prevent this precipitation.

Dilute sulphuric acid, or soluble salts containing it, throw down lime from concentrated solutions as a white precipitate of sulphate of lime, $CaOSO_3$, perfectly soluble in acids, and also in large proportions of water. In less concentrated solutions, the precipitates are only formed after the lapse of some time; and no precipitation whatever occurs in very dilute solutions. If solutions of lime are not sufficiently concentrated, the addition of alcohol will cause the immediate precipitation of sulphate of lime.

Oxalic acid produces a most characteristic precipitate of oxalate of lime, $CaO,\overline{O}+2$ aq, in dilute or strong solutions, and the detection of the lime with oxalic acid is rendered more certain by the subsequent

addition of ammonia, or by using oxalate of ammonia instead of the acid.

The soluble salts of lime improve the red colour of the flame obtained by burning alcohol containing nitrate of strontium, and indeed, the colour so obtained with lime salts is frequently mistaken for that of strontium.

Fig. 237. Immense specimen of Calc Spar, called Double-Refracting Spar, from Professor Tennant's collection. Proportions, nine inches high, seven inches and three-quarters broad, five inches and a half thick; estimated value, one hundred pounds.

Fig. 237. Scene of the Labours of Ceres.

CHAPTER XVIII.

CERIUM.

THE good, kind goddess who presides over the material for the "quartern loaf," gives the name to this metal, which was discovered in 1803 by Hisinger and Berzelius, in a mineral that comes from Sweden called "cerite," and found only in the Bastnaes copper mine near Ridderhyttan. The mineral consists, according to Klaproth, of—

Silica	34·5
Protoxide of cerium	50·75
Peroxide of iron	3·5
Lime	1·25
Water	5·0
Loss [?], oxides of lanthanium, didymium, &c.	5·0

It is stated to be a white, brittle metal, volatile at high temperatures, and soluble in aqua regia. It is not as yet applied to any useful purpose, although it might prove to be valuable in the state of oxide for painting on porcelain or colouring glass. The equivalent of cerium is 47, and it forms with oxygen a protoxide, CeO, and peroxide, Ce_2O_3.

lute alcohol, prepared by distilling ordinary alcohol from chloride of calcium, is slightly warmed and thrown suddenly on crystals of chromic acid, the oxidation takes place so rapidly, that the remaining alcohol usually catches fire. Warington has recommended chromic acid in a certain voltaic arrangement, described in the "Transactions of the Chemical Society" (vol. i. p. 61):—

"My first endeavour was to substitute this mixed fluid (bichromate of potash, 206·9, concentrated sulphuric acid, 275·8) for the nitric acid in the powerful arrangement of Professor Grove, so as, if possible, to obviate the inconvenience arising during the action of that battery, without diminishing the splendid effects produced by it. In doing this, it was absolutely necessary, from the nature of the materials to be employed, to modify to a certain extent the details of the construction of the battery, retaining the metallic elements unaltered, but enlarging considerably the cell appropriated for the nitric acid."

Second Series.

A solution containing oxide of chromium is not examined without attracting observation from its emerald-green colour. The sesquioxide of chromium, like alumina, is soluble in potash, and precipitated by chloride of ammonium; and by fusion with nitre, the oxide is converted into chromic acid, which yields with solutions of lead either the yellow or orange chromates of lead; indeed, the chromates are all red or yellow—the neutral solutions affording yellow chromates, or red on the addition of acid.

Nitrate of silver gives a dark reddish-purple precipitate of chromate of silver, soluble in nitric acid and ammonia.

Chromic acid is reduced to the state of oxide by oxalic, citric, tartaric, and sulphurous acids, and by hydrochloric acid and alcohol. Any chromate fused with borax yields a beautiful emerald-green colour.

Chromic acid in combination with chlorine, as chloro-chromic acid, $CrCl_3 2\,C_2O_3$, is perhaps one of the most, if not the most powerful oxidizing agent with which we are acquainted. It is easily prepared by fusing together ten parts salt and seventeen bichromate of potash. When cold, the mass is broken into small lumps and placed in a retort with thirty parts of oil of vitriol, and heat applied, when a vapour distils over, which must be carefully condensed. It is a dark, reddish-brown liquid, very volatile, and emits dark-brown vapours; if hydrogen is passed through a tube containing pumice moistened with chloro-chromic acid, and burnt, the flame is white, and deposits the green sesquioxide of chromium upon any white porcelain plate or cup held in the flame.

Fig. 239. Kobold, the Gnome or Sprite supposed to haunt the German Mines.

CHAPTER XX.

COBALT.

THE supposed origin of the name of cobalt is apparent from the vignette and description at the head of this chapter; but whether the Germans really had a superstitious dread, like the Cornish miners, of evil spirits, or whether they simply abhorred the presence of cobalt because they considered it useless, and only wasting their time (by obliging them to remove it to obtain more valuable minerals), is not perhaps fully known; an odd mixture of both ideas may perhaps have pervaded their minds, as they, like the "Roundheads," who prayed against Prelacy, Popery, and Peveril

of the Peak, also invoked the good powers against *kobalts* and *spirits*. Truly, knowledge is power, for the cobalt ores of Hesse were formerly used to repair the roads, and now yield a profit of many thousands per annum.

The metal is obtained either by heating the oxalate of cobalt in a glass tube like tartrate of lead (and is then pyrophoric when brought into contact with the air), or it may be obtained by passing dry hydrogen gas over oxide of cobalt heated to redness in a hard German glass tube: in this state (like many other metals) it is also spontaneously combustible. Cobalt has a specific gravity of 8·5; it is moderately brilliant, and requires a powerful heat for its fusion. Like iron, it is attracted to the magnet, and may, indeed, according to Wenzel, be made into a magnetic needle. In olden time, all the cobalt ore came from Germany, but now large quantities are obtained from Cornwall, Cumberland, and the Mendip Hills. The chief ores of cobalt are—

Name.	Composition.
Tin-white cobalt ore, or arsenical cobalt, or smaltine	Cobalt, iron, nickel, copper, bismuth, arsenic, and sulphur.
Cobaltine, or bright white cobalt, or glance cobalt	Cobalt, iron, arsenic, and sulphur.

Smaltine and cobaltine are used in preparing zaffre, which is merely the ore calcined to drive off the arsenic, and afterwards powdered. Smaltine is roasted and melted with pounded quartz or glass, and smalt, a compound used most extensively for the cheap blue patterns of crockery-ware, and especially for an old friend, the "willow pattern," Fig. 240. A very minute quantity of the oxide of cobalt is sufficient to impart the blue colour to the design, and it is stated that one grain of the oxide will give a full blue to 240 of glass.

Experiments with Cobalt.

First Series.

The equivalent for cobalt is 29·5, and it unites with oxygen in two proportions, viz.:—

Protoxide of cobalt	CoO
Sesquioxide of cobalt	Co_2O_3

Cobalt, dissolved in nitric acid, may be precipitated with a solution of potash as the blue hydrated oxide of cobalt, convertible by heat, but out of contact with the air, into the protoxide of cobalt. The hydrated oxide, suspended in water, is converted into black hydrated sesquioxide by passing chlorine gas through it, and on heating the hydrate, it is converted into the sesquioxide of cobalt. A beautiful red liquid is obtained by dissolving oxide of cobalt in ammonia, and is used in a dilute state for chemists' show bottles. The nitrate of cobalt is a valuable blowpipe reagent, and yields a beautiful green with oxide of zinc, or blue with

alumina, and a feeble rose tint with magnesia. The substances under examination may be powdered, heated on charcoal, and then moistened with the smallest drop of a solution of the nitrate of cobalt, and finally heated to redness. Silica also affords a blue colour with the same reagent, but the intensity is very different from that of alumina.

Second Series.

By dissolving the oxide of cobalt in hydrochloric acid, a pink solution of the chloride of cobalt is obtained, which turns to blue when it is evaporated to dryness; hence the use of this solution for sympathetic or invisible ink, which becomes apparent when the writing is held to the fire. The idea of such secret communication is not new, for Ovid mentions the use of milk for writing, which may be rendered visible by dusting on soot; and Pliny recommends the milky sap of plants, such as the dandelion, for the same purpose. The first use of the solution of cobalt as an invisible ink is ascribed to Hellot. The discoverer appears to have been a German named Stolberg, who probably met with the *kobalt* in his visits to certain mining districts, and trying the effect of aqua regia upon it, produced a red salt, that turned blue on exposure to heat. The following are the different solutions of cobalt which are invisible until another reagent, or heat, is applied.

Green sympathetic ink consists of a solution of acetate or chloride of cobalt with a small quantity of a salt of nickel and a little chloride of calcium to keep the writing damp; when heat is applied, a bluish-green colour appears.

Blue is obtained by writing with a dilute solution of nitrate of cobalt, and then washing it over with one of oxalic acid, and heating it strongly before a fire.

Third Series.

Chloride and sesquichloride of cobalt are known to chemists; the former, CoCl, is prepared by dissolving the oxides of cobalt in hydrochloric acid, when a beautiful pink-coloured solution is obtained; which, if carefully evaporated and crystallized, affords pretty rose-coloured crystals of the chloride combined with water. The solution of chloride of cobalt is green when it contains iron or nickel, or blue if it contains an excess of acid. The red again appears if it is mixed with a large quantity of water.

When the hydrated chloride is heated, it parts with the combined water, and becomes blue; hence the use of the chloride in the preparation of sympathetic ink. Letters written with the pink chloride are invisible until held before the fire, when they appear blue; and if a little salt is mixed with the chloride, it is not so likely to remain permanently blue, as will happen sometimes when too much heat is applied.

Fourth Series.

Cobalt is detected by the blowpipe when a drop of any of its solutions is heated red-hot in conjunction with oxide of zinc, alumina, or silica, as already described.

Sulphuretted hydrogen precipitates with difficulty a black sulphide from neutral, but not from acid solutions of cobalt.

Sulphide of ammonium completely precipitates the sulphide from neutral and alkaline solutions of cobalt.

Potash precipitates a dirty blue, which changes to green when exposed to the air.

Ammonia precipitates and redissolves the oxide of cobalt, forming a beautiful red solution.

Fused borax, powdered and moistened with a solution of cobalt, and then taken up on a platinum wire loop, and heated by the blowpipe flame, yields that characteristic blue which is so usefully employed in colouring glass and china.

Fig. 240. The Willow Pattern Plate. An illustration of the use of the oxide of cobalt; being the much-lamented Albert Smith's last advertisement.

Fig. 241. The Rainbow, which is typical of the multiplicity of colours obtained from metals.

CHAPTER XXI.

DONARIUM, DIDYMIUM, ERBIUM, GLUCINUM, ILMENIUM, IRIDIUM, LANTHANIUM, AND LITHIUM.

THE first-named metal was discovered by Bergmann, in certain minerals from Norway. The second, so called from *Didumos*, "twins," a fanciful allusion to its connexion with lanthanium, is extracted from cerite, a mineral already alluded to at p. 447, in the article "Cerium." M. Marignac has published some valuable researches on didymium and its principal compounds, and has also determined the atomic weights of cerium and lanthanium, and approximatively that of didymium.

	Atomic weight.
Cerium	47·26
Lanthanium	47·04
Didymium	49·4

Erbium is obtained from a mineral called gadolinite, composed, according to Berzelius, of

Silica	25·8
Yttria	45·0
Protoxide of cerium	16·69
Protoxide of iron	10·26
Water	·60
Loss [?], oxide of erbium	1·65
	100·00

Glucinum has already been mentioned as a constituent of the emerald, which is a double silicate of alumina and glucinum, coloured with oxide of chromium. The beryl and chrysoberyl also contain it.

Ilmenium.—The existence of this metal has been challenged by Rose; indeed, many more experiments are required to be made with some of these alleged new metals before they can be said even to exist.

The latter metal is stated to have been discovered by Hermann, in Siberian yttro-tantalite, or rather Samarskite, but H. Rose showed that he had mistaken niobic for ilmenic acid, and, therefore, that such a metal did not exist.

Iridium deserves special notice, because, although rare, it is now used in the shape of the very hard native alloy of osmium and iridium, for the tips of the so-called gold pens; it is likewise employed in the state of oxide, to produce a most intense blackness in painting on porcelain; and it is stated by Dr. Percy that all other porcelain black colours appear grey by the side of it. It is not, perhaps, surprising that iridium should be remarkable for its qualities as a pigment, when we search into the origin of the name, which refers to its colour-giving powers as if it were similar in this respect to an iridescent soap-bubble, or the pretty iris produced by the deposit of dew on the spider's web (Fig. 242).

Lanthanium is also derived from the mineral cerite, and the only oxide known is a white powder!

Lithium is the lightest metal known, having only a specific gravity of 0·5936, and is obtained from the oxide of lithium or lithia, which occurs in various minerals, and especially in petalite and spodumene, which are silicates of alumina and lithia, containing about nine per cent. of the latter.

Professor Bunsen, in a letter to Liebig, describes his method of preparing lithium:—"Pure chloride of lithium is fused over a Berzelius spirit-lamp in a small thick porcelain crucible, and is decomposed by a zinc coke battery, consisting of four to six cells. The positive pole is a splinter of gas coke (the hard carbon deposit in the gas retort), and the negative an iron wire about the thickness of a knitting-needle. After a few seconds, a small silver-white regulus is formed under the fused chloride round the iron wire and adhering to it, which, after two or three minutes, attains the size of a small pea: to obtain the metal, the wire pole and regulus are lifted out of the fused mass by a small, flat-

spoon-shaped, iron spatula. The wire can then be withdrawn from the still melted metal, which is protected from ignition by the chloride of lithium with which it is coated. The metal may now be easily taken off the spatula with a penknife, after having been cooled under rock oil. As this operation can be repeated every three minutes, an ounce of chloride of lithium may be reduced in a very short time.

Lithium, on a fresh-cut surface, has the colour of silver, but tarnishes after having been exposed for a few seconds to the air, and becomes slightly yellow. The melting-point is 180° C. A piece of it at that temperature, if pressed between two glass surfaces, exhibits the colour and brightness of polished silver. Lithium is harder than potassium or sodium, but softer than lead, and therefore can be pressed out, like that metal, to wire. By pressure lithium can be welded at ordinary temperatures; it swims on rock oil, and is the lightest of all solid bodies.

The salts of lithium are stated to impart a red colour to the inner blowpipe flame; and lithia, LiO, is usually considered to be the intermediate link between the alkalies and alkaline earths. The atomic weight of lithium is 81·7.

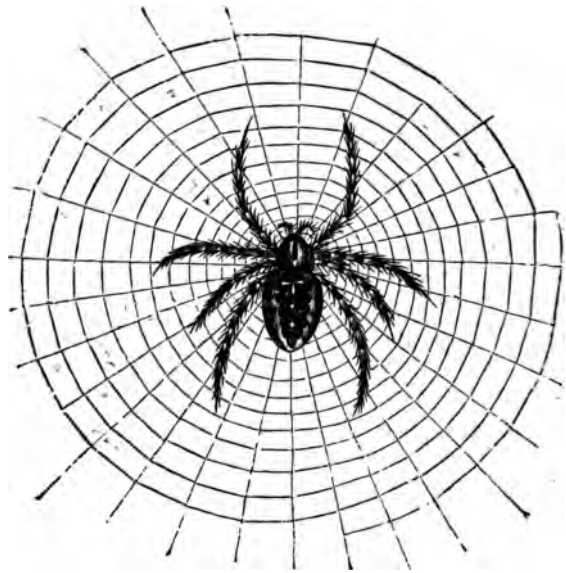


Fig. 242. The Spider's Web upon which dew deposits, and, when lighted by a sunbeam, produces the beautiful prismatic colours of the iris, the origin of the word iridium.

Fig. 243. Domestic Use of Magnesia and its Sulphate.

CHAPTER XXII.

MAGNESIUM.

This metal is another of the metallic bases of the earths, and claims Davy for its discoverer. Bussy, however, in 1830, prepared it in much larger quantities by a somewhat similar process to that used by St. Clair Deville with alumina. Bussy employed chloride of magnesium, which he decomposed by potassium, with the assistance of heat. The metal has the following properties: it is brilliant, silvery white, perfectly ductile and malleable, fusible at a moderate temperature, like zinc, volatilized at a temperature a little higher than that of its melting point, and, like that metal, condenses into small globules. It has a specific gravity of 1·743, and does not decompose water at common temperatures; it oxidizes at a high temperature, and is slowly converted

into magnesia when in small masses; but when finely divided, as in filings, it burns with great splendour, throwing out sparks like iron in oxygen.

Magnesium has lately been made in much larger quantities, and can now be obtained at a moderate price, so that enthusiastic practical men have suggested its employment as a magnesium lamp, on account of the very great brilliancy of the light which it evolves during combustion; indeed, nothing can be more brilliant than this union of oxygen gas with magnesium. Dr. Matthiessen recommends the use of a mixture of the chlorides of potassium and magnesium in nearly equal proportions, instead of the anhydrous chloride; the quantities are three equivalents of chloride of potassium to four of chloride of magnesium. The solution of the chloride of magnesium can be evaporated almost to dryness, and analysed to find the amount of the anhydrous salt present. After having mixed the two salts in the proper proportions with some chloride of ammonium, the mixture may be fused and electrolysed by Bunsen's method, the pockets not being required, as the metal is specifically heavier than the fused mixture. A very simple and convenient way of reducing the metal, especially for the lecture-table, is in a common clay tobacco-pipe, over a Berzelius spirit-lamp, the negative pole being an iron wire put up the pipe-stem, and the positive being a piece of gas coke just touching the surface of the fused chlorides.

The minerals that contain magnesium are found in very large quantities, and amongst them may be specially noticed the following; viz.—

Name.	Composition.
Dolomite, or magnesian limestone.	Carbonate of magnesia, carbonate of lime, with some oxide of iron and manganese, silica, and alumina.
Steatite, or soapstone, a variety of which is called Spanish chalk, whilst another is used by certain savage tribes as a portion of their food; another is called meerschaum, of pipe celebrity; a fifth serpentine; a sixth variety is asbestos, or amaranthus, of which the fibres are elastic and flexible, and used in the manufacture of incombustible cloth; a seventh, talc, used frequently instead of glass for windows; and an eighth, potstone, which is formed into culinary vessels in Greenland and Hudson's Bay.	Silica, magnesia, with some alumina, oxide of iron, manganese, potash, and lime.
Magnesian mica	Silica, alumina, magnesia, with some oxides of iron, potash, fluoric acid, and water.

Certain spring waters retain an abundance of sulphate of magnesia in solution—such as the Norwood and Epsom springs, of which the latter has given the name to that popular, because cheap, medicine called "*Epsom salts.*" The water of the ocean likewise contains a large quantity of magnesia. The well-known medicine called calcined magnesia is prepared by precipitating a solution of magnesia by boiling it with one of carbonate of soda; the carbonate is then well washed and calcined, and by the application of a proper heat is converted into magnesia, MgO.

The equivalent of the metal magnesium is very low, being only 12; and it has for that reason, in a great measure, been proposed as a light-giving agent. The equivalent of carbon is 6, and therefore, if the metal could be procured at a very cheap rate, there is no reason why it should not be used for special purposes of illumination. The only oxide known is magnesia, the preparation of which has already been described. This alkaline earth, in the state of carbonate, is freely dissolved by carbonic acid, and has been employed most efficaciously for many years as a domestic medicine under the name of "Dinneford's fluid magnesia."

If water is added to calcined or caustic magnesia, it does not combine chemically with, and "slacken" this earth, like lime, baryta, or strontia; neither does magnesia absorb carbonic acid from the atmosphere, hence caution must be used in selecting and burning limestones for agricultural purposes, on account of the magnesia remaining in an alkaline or caustic state.

Dr. Wollaston, whose laboratory consisted of a tray containing a few bottles, watch glasses, and glass tubes, &c., was the first to point out an elegant method of detecting magnesia in minerals supposed to contain it. "Dissolve with aqua regia in a watch glass a *minute* fragment of the mineral; and if it is not soluble, it must be rendered so by previous fusion with carbonate of soda. Render the solution neutral by cautious evaporation; then, while hot, add a little oxalate of ammonia, to precipitate any lime which it may contain. Let the precipitate fall, and take a few drops of the clear liquid, and put them on a slip of window glass. Add a *drop* or two of bicarbonate of ammonia, and afterwards a *drop* or two of biphosphate of ammonia. Then draw a little of the clear solution to one side of the slip of glass, and trace any letters or lines across it with a glass rod. On exposing it to a gentle heat, *white traces* will be perceived wherever the rod was applied."

Ammonia precipitates from the solutions of neutral salts of magnesia a portion of the magnesia as hydrate of magnesia (MgO,HO); the other portion remains in solution, forming a double-salt with the ammonia perfectly soluble in water. It is this circumstance which renders Wollaston's method of detecting magnesia so important, because of the insoluble basic phosphate of ammonia and magnesia ($2MgO,NH_4O$) ($PO_5+2HO+10aq$) produced in the presence of an excess of ammonia by the addition of a solution of phosphate of soda *to* one of magnesia.

Fig. 244. The Chameleon.

"Of the chameleon's food I eat (the air)."
HAMLET.

CHAPTER XXIII.

MANGANESE.

THE little animal that heads our present chapter has given rise to much discussion, in consequence of the curious changes of colour that it is said to be capable of producing at its own will and pleasure; and the fanciful writer has little difficulty in assuming that the animal suffers from anger when he turns red; jealousy, of course, if yellow; but is amiable and serene when blue. Into these varieties of colour or temper, of course, we do not enter; but merely state that manganese is capable—like antimony, chromium, arsenic, tellurium, tungsten, and others—of forming acids with oxygen; and that this compound is called manganic acid, which, in combination with potash and dissolved in water, affords a complete series of spontaneous chromatic changes of the most curious description; and, indeed, from this curious circumstance the salt is called "Chameleon Mineral," and its preparation and composition will be explained in another part of this chapter.

The metal manganese, so called, according to Sir Robert Boyle, from its resemblance to the magnet, appears to have been known only in combination with oxygen gas in the common mineral called "black oxide of manganese;" and it was this accomplished philosopher who discovered the first mine of it in England. The mineral was used 2000 years ago, and is now employed in the manufacture of the best crystal or flint glass, to which it is said to confer a greater brilliancy in consequence of the delicate amethystine colour it imparts to this siliceous mix-

ture. Moreover, it does to all intents and purposes bleach the glass whilst the materials are in a state of liquefaction and incorporation, by giving oxygen to any carbon or protoxide of iron that may be present, and discolour the pot of glass; hence it is called "Glass Maker's Soap:" the oxygen it contains burns away the carbon, and at the same time converts the protoxide of iron into peroxide, which is colourless when united with silicic acid.

This metal, after evading the processes of Boyle, Glauber, Haig, Pott, Kaim, Bergmann, and Scheele, at last rewarded the persevering efforts of chemists, by appearing to the summons of Dr. Gahn, who, by mixing some black oxide of manganese with oil in balls, and placing them in a *crucée brasquée*, or crucible lined with charcoal, and then applying a most intense and vigorous heat, was rewarded (Chinese fashion) with a button, or rather a number of small metallic globules, equal in weight to one-third of the mineral used. The charcoal, of course, removed the oxygen, and the manganese remained in the metallic state. To purify the button of manganese, it should be fused again with some pure carbonate of manganese and borax. The metal has a specific gravity of 7·05, and presents a grey colour; it is hard and brittle, readily oxidizes when exposed to the air in the moist state, and decomposes water at the boiling point, but very slightly, if at all, at ordinary temperatures.

Experiments with Manganese.

First Series.

The equivalent of manganese is 27·6, and it combines with oxygen in five different proportions, viz.:—

Protoxide of manganese	MnO.
Sesquioxide of manganese	Mn_2O_3.
Peroxide of manganese	MnO_2.
Manganic acid	MnO_3.
Permanganic acid	Mn_2O_7.

Of these, the most interesting is the peroxide, which occurs in nature under the name of pyrolusite, or black oxide of manganese, and is used largely in the manufacture of chlorine for bleaching purposes, likewise in the preparation of oxygen gas; and as both processes are fully described in the "Playbook of Science," it is unnecessary to repeat them here.

Manganic acid, although not yet isolated, is known to exist in combination with other bases; and amongst its salts is the manganate of potash, or "chameleon mineral ($KOMnO_3$), first discovered by Scheele, who fused together equal parts of nitre and black oxide of manganese, and dissolving the green compound in water, obtained a fine red solution, which in consequence of presenting a green colour when made with boiling water, and a purple or red with cold, likewise changing by acids from green to rose or red colour, was named after the extraordinary animal already alluded to.

Manganic acid is a powerful oxidizing agent, and in contact with organic matter is quickly converted into the sesquioxide of manganese.

Permanganic acid (Mn_2O_7) is prepared by first carefully mixing together four parts of powdered black oxide and three and a half of chlorate of potash, to which five parts of potassa fusa, or stick potash, dissolved in just enough water to make a paste with the other ingredients, are added. The paste is then dried in an oven, and fused in a crucible for one or two hours, and when cold is dissolved in water and allowed to settle in a well-stopped bottle, and the clear solution decanted and evaporated at a very low temperature, when crystals of the permanganate are obtained. Lately, Machuca has carefully analysed the permanganate of potash, and his researches not only prove the existence of the acid, but the truthfulness of the formula $KOMn_2O_7$.

The oxidizing powers of this acid are truly remarkable; and by making a standard solution of the permanganate of potash, Dr. Smith, of Manchester, has detected organic matter in the air. It is this salt, mixed with the manganate of potash, which is the basis of Condy's disinfecting fluid, a most excellent deodorizer, and satisfactory in its result, because the operator can always tell when it has done its work by the solution becoming colourless. Amongst the recommendations of the patentee in the use of Condy's fluid is the following:—Pour one wine-glassful of the concentrated fluid into a hogshead of offensive drinking-water, and stir it up with a stick or lath; generally this quantity will render it as sweet as fresh water. Should it be so bad as to require another half wine-glassful, let it be added, and when the sesquioxide of manganese has settled it may be run off and drank, or if filtered after the addition of the permanganate, will be found as sweet and good as fresh water.

Mr. Wildsmith, analytical chemist, of Wolverhampton, has made the permanganate in large quantities, and states that it can be sent into the market at 150 per cent. below its former rate. Mr. Horsley states that the powdered black oxide of manganese is likewise an excellent disinfectant; and he states that a most powerful and cheap deodorizer is obtained by mixing three parts of the black oxide and one of chloride of lime. The use and value of manganese, in conjunction with iron, in the manufacture of the best steel, has been already alluded to.

Second Series.

Manganese is detected by the colour it produces when oxidized with nitre or chlorate of potash and dissolved in water; and by the precipitation of the sesquioxide of manganese of a brownish-black colour, on the addition of organic matter.

The protosalts of this metal are not precipitated by sulphuretted hydrogen, except from alkaline solutions.

Sulphide of ammonium throws down from protosalts the sulphide of manganese (MnS), as a bright flesh-coloured precipitate.

Potash and ammonium precipitate protosalts as a white hydrated protoxide, which gradually changes from white to brown and brownish

black by exposure to the air. The reactions of the hydrated oxide are taken advantage of in dyeing and calico printing.

Any salt or compound of manganese fused with carbonate of soda, on a platinum wire loop in the outer flame, affords a green colour as long as the little bead of soda is hot, but when cold it changes to a bluish green, and becomes opaque. Borax and phosphate of soda and ammonia dissolve the compounds of manganese in the outer flame of the blowpipe, and produce bright violet-red glasses, which, on cooling, appear of an amethystine red tint; these, however, lose their colour when subjected to the inner part of the blowpipe flame, owing to a change in the condition of oxidation, by which the peroxide of manganese is changed to the protoxide. If an excess of peroxide of manganese is fused with borax, the glass bead is black; hence the use of this cheap compound of manganese, not only in whitening, but also in conferring a black colour on some kinds of glass. The glass bead formed in the loop of platinum wire by melting oxide of manganese with phosphate of soda and ammonia never dulls or loses its transparency.

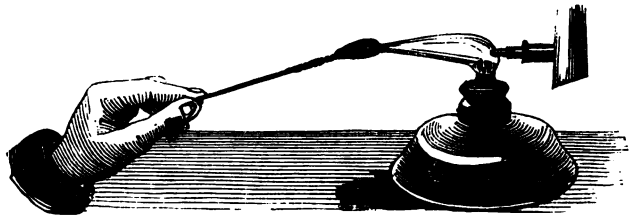


Fig. 245. Manganese Compound, fused on a loop of platinum wire with phosphate of soda and ammonia, which is sometimes called microcosmic salt.

Fig. 246. View in the Hartz Mountains, from whence numerous kinds of minerals are obtained.

CHAPTER XXIV.

MOLYBDENUM.

NEARLY every mineral cabinet contains a specimen either of molybdenite, the sulphide of the metal; or of molybdate of lead, called wulfenite. The following is the composition of molybdenite, according to Brandes:—

Molybdena	59·6
Sulphur	40·4

Domeyko has given the analysis of wulfenite, or molybdate of lead from Chili, which consists of—

Protoxide of lead	43·0
Molybdic acid	42·2
Peroxide of iron	8·5
Lime	6·3
	100·0

This rare metal may be procured either by decomposing molybdic acid at a white heat with hydrogen, or by exposing it to the intense heat of a wind furnace in a crucible lined with charcoal. Thomson remarks, that hitherto the metal has been obtained only in small grains or in pieces imperfectly agglutinated, and which break readily when struck. Its colour, from the observations of Bucholz, seems to be a silvery white, but it frequently has a shade of yellow. Hjelm found its specific gravity only 7·400; but Bucholz, whose specimens had doubtless been exposed to a more violent heat and were more compact, found it as high as 8·615, or even 8·636. Molybdenum is brittle. It is not altered, even if kept under water. Its affinity for oxygen is not great. Hence it is not liable to undergo alteration when exposed to the atmosphere.

When the metal is heated to redness in an open vessel, it absorbs oxygen, and is converted into a brown powder, which becomes reddish if the heat be long continued, and at last, according to Bucholz, becomes blue. When the heat to which the metal is exposed is still higher, the molybdenum takes fire and burns without flame, smokes, and deposits small, brilliant, white needles, which constitute molybdic acid.

Very little is known about the metal, and it is interesting to the chemist because it forms with oxygen another metallic acid, molybdic acid, composed of three equivalents of oxygen and one of molybdenum (MoO_3), likewise a binoxide (MoO_2), and protoxide (MoO). Phosphoric acid appears to be one of the most conclusive tests for this metal, although a thorough practical knowledge of its behaviour with this and other reagents is necessary in order to enable the chemist to discover its presence, and not to lose sight of this element, should it come accidentally before him.

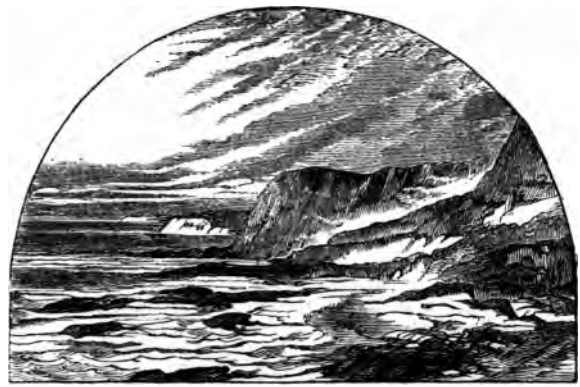


Fig. 247. The Coast of Cornwall, being one of the localities where *molybdenite* is found.

Fig. 248. Aërolite, or Meteoric Stone, in British Museum.

CHAPTER XXV.

NICKEL.

This metal introduces to our notice what Humboldt terms "an enigmatical class of bodies," called minute "asteroids," "aërolites," or "meteoric stones,"—travellers that come to us out of space, fortunately at rare intervals, but of whose permanent visits to this globe there cannot be any doubt. These metallic masses chiefly consist of iron, and have usually been distinguished by scientific men from other natural ores of iron in consequence of their containing nickel; although it ought to be understood that they include in their composition, according to the analyses of Ber-

zelius, the same elements that are usually found in the crust of the earth—viz., iron, nickel, cobalt, manganese, chromium, copper, arsenic, tin, potash, soda, sulphur, phosphorus, and carbon, being rather less than one-fifth of the number of elements already known. A great many theories have been suggested to account for these strange mineral truants, who leave their usual path and turn aside to the earth. Some astronomers have asserted that they are projected from volcanoes in the moon; but Humboldt, in his "Cosmos," remarks that, "It is probable that the different streams of meteors, each consisting of myriads of small cosmical bodies, intersect the orbit of the earth in the same way that Biela's comet does. According to this view, we may imagine that they form a continuous ring, each pursuing its course in a common direction. The small planets between Mars and Jupiter present, with the exception of Pallas, an analogous arrangement in their closely-connected orbits. . . . . The highly ingenious Olbers was inclined to think the next return of the great phenomenon of fire-balls and shooting stars, *falling like flakes of snow*, would be witnessed from the 12th to the 14th November, 1867." The instances of the fall of these solid masses are very numerous: thus, on the 16th September, 1843, a large aërolite fell at Kleinwenden, not far from Mulhausen, accompanied by a thundering noise, but with a clear sky in which *no cloud* was formed. In another case, a small and very dark cloud formed suddenly in a perfectly clear sky, and the stones were hurled from it with a noise resembling repeated discharges of cannon. Such a cloud, moving over a whole district of country, has sometimes covered it with thousands of fragments, very various in size but similar in quality. Humboldt further remarks: "They exhibit, on the whole, a general unmistakeable resemblance to one another in their external form, in the nature of their crust, and in the chemical composition of their principal constituents; and this resemblance is traceable when and wherever they have been collected, at all periods of time, and in all parts of the earth." In the Lithuanian mythology a beautiful symbolical meaning has been attached to these "falling stars." The new-born infant's destiny was supposed to be attached by a thread to a star, and when it fell the child died, and the thread was broken for ever. In consequence of the density of their chemical composition, they have been divided into two classes, viz.—

Nickeliferous meteoric iron.
Fine or coarse-grained meteoric stones.

Enough, then, has been said to prove that one of the sources of nickel is to be found in the aërolites that wander in space; but as this nickel happens to be rather largely used just now for the whitening agent in the manufacture of nickel silver, or German silver, it would not be a very profitable or prudent course to wait, like fags at cricket, till the balls containing it come to hand; so the diligent miners seek for it in the earth, and are rewarded with certain minerals that contain it: viz.—

Name.	Composition.
Copper nickel, or *kupfer nickel.**	Nickel, cobalt, arsenic with a little iron, lead, antimony and sulphur, *but no copper.*
Antimonial nickel	Nickel, antimony, sulphur, arsenic, with occasionally a little iron.
Nickeline, or nickel ochre, or *nickel arseniate*	Oxide of nickel, arsenic acid, sulphuric acid, oxide of cobalt, oxide of iron, water.
Chrysoprase, a variety of quartz	About one per cent. of the oxide of nickel.

Solutions of nickel are specially distinguished by their peculiar grass-green colour, and if precipitated by oxalate of ammonia, an oxalate of nickel is obtained, which, if it contains cobalt, must be dissolved in ammonia; and being left to evaporate spontaneously, the nickel is deposited as the ammonio-oxalate, whilst the cobalt remains in solution. When this ammonio-oxalate has been thoroughly dried, it is placed in a closed plumbago crucible, and exposed to the strong heat of a wind-furnace, by this means the carbon and oxygen of the oxalic acid are converted into carbonic acid, which passes away, and the nickel remains behind in the metallic state.

In a state of purity, nickel is of a beautiful white colour, brilliant, and, like silver, leaves a mark on the touchstone: it has a specific gravity of 8·5, and its equivalent is 29·6. Nickel is malleable both hot and cold, and, like cobalt, is attracted by the magnet; and nickel needles may be constructed, magnetized, and suspended like ordinary steel ones. This metal forms poisonous salts, and therefore "German silver" articles must never be exposed to vinegar or other acid matter, and should be kept scrupulously bright and clean. Oxide of nickel (like the oxides of iron, copper, &c.), when heated and exposed to a current of dry hydrogen gas, is reduced to a pyrophoric metallic state: it is stated that when heated, nickel passes through nearly the same phases of colour which are perceptible if steel is tempered. In a lecture delivered by Dr. Percy, on "The Importance of Special Scientific Knowledge to the Practical Metallurgist," at the Government School of Mines, he stated that—

"It is only a few years ago that, in respect to commercial value, nickel occupied much the same position as tungsten, but now it is worth eight shillings a pound, or about ten times more than copper. It is the whitening constituent of the alloy known as 'German silver.' The silver-platers who practise the old method of plating by soldering, as well as those who deposit the silver by the agency of voltaic electricity, employ this alloy extensively, the advantage being, that when the silver is worn from any part of an article, the alloy beneath suffi-

* The name of this mineral is the origin of the word nickel. "Kupfer nickel" means false copper, because the miners at first mistook it for that metal, and threw it away as useless, when unable to extract any copper from the mineral.

ciently approximates to silver in whiteness as to deceive the eye respecting the wear. Some years ago, a compound of nickel, termed pottery nickel, was obtained in the manufacture of compounds of cobalt, for the use of the potters, which was sold as low as three-halfpence a pound, whereas it would now fetch about three shillings and sixpence."

The late Mr. Henry Bradbury, who distinguished himself so highly in the perfection of the printing process termed "nature printing," has found that by depositing nickel on the surface of copper or steel engraved plates, they last an indefinite period if occasionally re-nickelized by the voltaic current in a bath containing a solution of the sulphate of the protoxide of nickel in ammonia.

EXPERIMENTS WITH NICKEL.

First Series.

There are two oxides of nickel—viz., the protoxide, NiO, and the sesquioxide, Ni_2O_3, and when a solution of potash or soda is added to one of the protoxide of nickel in sulphuric acid (that being the acid which appears to be the best solvent of the metal), a beautiful light apple-green precipitate is thrown down, being the hydrated oxide, NiO,HO.

Nickel dissolves in nitric acid, and by evaporating the solution and calcining the residue at a moderate heat, there remains behind the sesquioxide of nickel.

Second Series.

Copper plates, as already observed, may be coated with nickel, and in that state exercise a curious influence upon the magnetic needle. Boettgher states that copper plates assume a silvery-white shining surface after exposure to a long-continued and constant galvanic action in a solution of the ammonio-sulphate of nickel, and, when covered, they have sufficient magnetic power to bring a magnetic needle suspended by a thread of raw silk out of the meridian. A drop of concentrated nitric acid placed on a coating of nickel gives no evidence of reaction on the metal below it, whilst a copper plate covered with gold in the same space of time is strongly acted upon by the acid. As pure nickel is as difficult to melt as iridium or manganese, and is, in fact, not to be fused except by the oxyhydrogen blowpipe, this metal, procured in the pure state (in the form of plate) by voltaic deposition, might be used for the construction of magnetic needles, &c.

Third Series.

In the chapter on the metal Tin, the preparation of "mosaic gold," by distilling an amalgam of tin and mercury with sulphur and sal ammoniac, is fully described. The chloride of nickel, NiCl, has a somewhat similar appearance to "mosaic gold," and is prepared by passing chlorine gas over nickel at a red heat, when it sublimes in fine plates of

a beautiful golden yellow colour; which if heated to redness in hydrogen gas, afford brilliant metallic nickel.

Fourth Series.

Solutions of nickel are nearly always green. The protoxide is precipitated by ammonia as a lovely apple-green hydrated oxide, which is redissolved by an excess of the precipitate, and then turns *blue*.

Cyanide of potassium throws down a greenish-white precipitate of cyanide of nickel, NiCy, which is dissolved by an excess, and then forms a *brown*-coloured solution; but the original greenish-white, NiCy, reappears on the careful addition of an acid. In all experiments with the cyanides, and whenever acids are added to them, care must be taken not to inhale the hydrocyanic acid (prussic acid) fumes given off. More than one instance has occurred in olden times where the alchemist was found dead in his laboratory, killed by the poisonous exhalation of his experiments. Scott disposes of Alasco (in his novel of "Kenilworth") by this mode of retributive justice. The glass and its contents, placed on a piece of wood, or any other bad conductor of heat, may always be placed on one of the hobs of an ordinary fireplace, and the current of air which sets towards the fire will generally sweep it up the chimney.

Fig. 249. Mode of avoiding Dangerous Fumes.

CHAPTER XXVI.

NIOBIUM, NORIUM, OSMIUM.

With respect to niobium and pelopium—and we mention this metal out of the alphabetical order because of its association with niobium in the same mineral—Professor H. Rose says: "I have discovered in the tantalite of Bavaria two new metals: one I have called *Niobium*, and its acid, niobic acid, from Niobe, the daughter of Tantalus, a name which calls to mind the resemblance between the two metals and their oxides; and the other, *Pelopium*, from Pelops, the son of Tantalus, and the brother of Niobe. For more than four years I have been engaged in investigating the tantalites from various localities, and the tantalic acid derived from them." And it was by the searching examination of that which was supposed to be wholly tantalic acid, that these metals were eliminated in minute quantities. Niobic acid is said to resemble titanic acid and the binoxide of tin; both of these, when calcined in the hydrated state, present the same luminous phenomenon. Pelopic acid also resembles tantalic acid.

Norium, the existence of a new earth in Zircons, was first pointed out by L. Svanberg; and, by analogy, if a new earth, it must have a new metallic base, called *Norium*, from Nore, the old name of Norway; but the existence of this new metal seems doubtful.

Osmium.—This metal has already been alluded to in connexion with iridium, page 455, and it forms at least five compounds with oxygen gas, of which osmic acid is represented by the formula, OsO_4. The equivalent of the metal is 99·6, and specific gravity 10. It is stated to be a brittle metal having a greyish appearance, but when obtained in the metallic state from its solutions, osmium has a blue colour. These remarks on the colour and general appearance of the metal must probably be received with caution, because it is difficult to form any judgment of these points until a tolerably-sized bar of any new metal is obtained. The peculiar smell and the volatility of the osmic acid in the treatment of ores containing platinum are very marked, and it is from this peculiar circumstance that the metal osmium derives its name.

Osmic Acid (OsO_4).—This metallic acid appears to possess very feeble powers of combination, and is incapable of reddening litmus-paper or decomposing the carbonates of the earths or alkalies; still the vapours of osmic acid have always enjoyed a very bad reputation, and are stated to be extremely hurtful and irritating to the lungs of those who have performed experiments with it. Osmic acid is prepared by heating osmium with nitric acid in an alembic or retort; the vapours pass over with those of the nitric acid, and the osmic acid condenses in colourless prismatic crystals, which melt and sublime some degrees below 212° Fah. The chief source of osmium is from the alloy of iridium and osmium (osm-iridium), which is associated in nature with native platinum.

Fig. 250. Portrait of Sir Humphry Davy, the Discoverer of the Alkaline Metals.

CHAPTER XXVII.

POTASSIUM.

In 1807 the scientific world of Europe was gratified with the fulfilment of the prediction, that the bases of the fixed alkalies and earths were metals, by the ingenious experiments of Sir H. Davy, who discovered that potash can be resolved by an intense and powerful current of voltaic electricity into potassium and oxygen. The battery used consisted of two hundred pairs of four-inch plates; but the late Dr. Golding Bird devised a very simple arrangement with a single pair of elements, and decomposing cell, which will effect the same object as that obtained by Davy with his large battery. The single cell consists of an inner vessel,

B B, which may be an inverted lamp-glass closed at one end with plaster of Paris, seven-tenths of an inch in thickness, suspended by a wire (twisted round the shoulder) inside a sufficiently deep jar, A A. In the latter is placed a sheet of zinc with wire attached, z, and some weak

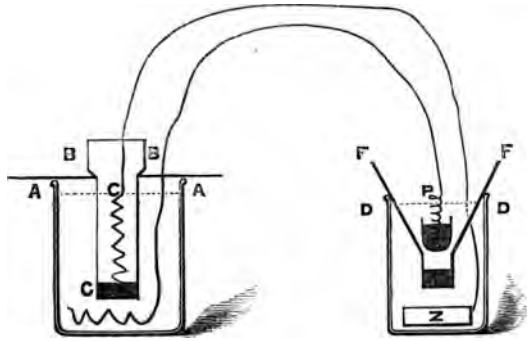


Fig. 251. A A. Outer vessel of the single-pair battery, containing a zinc plate and a solution of common salt. B B. Inverted lamp-glass closed at the bottom with plaster of Paris, and containing a copper plate, C, surrounded with a saturated solution of sulphate of copper. D D. Outer vessel or decomposition cell, containing a weak solution of common salt and amalgamated plate of zinc, Z. F F. The funnel closed with plaster of Paris, and holding the little cup of mercury covered and surrounded with a solution of chloride of potassium, P. G. Connecting wire.

solution of common salt, and in the lamp-glass is placed a sheet of copper, C, and wire attached of the same size as the zinc, surrounded with a saturated solution of sulphate of copper. The two liquids must be at the same level in each glass. The decomposition cell is the ditto of the miniature battery, and it consists of an inner vessel, such as a glass funnel, which is closed at the tube or narrow end with plaster of Paris, likewise seven-tenths of an inch in thickness, and contains a short glass tube, like a thimble, full of mercury, and the whole covered with a solution of chloride of potassium; the funnel is supported in an outer vessel containing a weak solution of common salt. In the latter solution is placed a slip of amalgamated zinc soldered to the wire coming from the copper plate of the miniature battery, and a platinum wire, P, coiled into a spiral at the extremity, is connected with the wire from the zinc plate of the little battery, and placed in the mercury contained in the short glass tube standing in and covered with the chloride of potassium in the funnel. After the circuit had been completed and maintained for nine hours, the mercury was found by Dr. Bird to have puffed up to twice its former bulk, and when this amalgam of mercury and potassium was thrown into water, it evolved hydrogen and produced an alkaline solution, just as potassium acts in the ordinary manner.

Potassium is obtained by the improved process of Mitscherlich, by exposing black flux, which is a mixture of charcoal and carbonate of potash, and lumps of charcoal, in a wrought-iron mercury bottle, to which an iron tube and copper receiver containing petroleum, and surrounded with ice, is attached. At the proper heat the metal distils over, and falling into the mineral naphtha is preserved from oxidation. After redistillation, it is found to be sufficiently pure, and is a soft solid at all ordinary temperatures, having a specific gravity of 0·865, water being 1·000. When cut with a knife, it exhibits considerable brilliancy and looks like lead, but is quickly dimmed over with the rapid oxidation and formation of potash (the oxide of potassium) on its surface. The vapour of potassium, like that of chlorine, is green. The most important oxide is potash, KO, always obtained when potassium is burnt on the surface of water; but there is probably a suboxide, K_2O, and a teroxide, KO_3, is also believed to exist.

Potash is one of the most important of the fixed alkalies, forming, with various acids, salts, such as nitre, carbonate of potash, chlorate of potash, ferrocyanide of potassium, and chromate of potash, &c., which are of the highest commercial value. Nitre, saltpetre, or nitrate of potash (KO,NO_5), is a salt which is produced spontaneously, and comes out as a sort of efflorescence on the surface of the soil in certain hot climates. It has been calculated that the soils of Spain, Egypt, and India might supply the whole world with this substance, and it is extremely satisfactory to feel that, as gunpowder is likely to be required in large quantities for those wars with which Europe is threatened, we hold possession of India, and have therefore a boundless supply of the "villanous saltpetre."

The superficial earth containing the nitre is broken up and thrown into large cisterns provided with false bottoms covered with straw, which act as the strainer does in a coffee-pot. These cisterns are usually arranged in a succession of steps or levels, so that the water poured upon the first quantity of the earth containing the nitrates may remain upon it for twelve hours, and then be run off (without the trouble of lifting or pumping) into the next lower cistern, also containing the nitre earth, and from that into the third or lowest cistern, likewise containing a quantity of earth. By this simple method the solution is made tolerably strong, and is usually termed the *lye*. This liquid, which not only contains the nitrate of potash or saltpetre, but also nitrates of soda, ammonia, lime, and magnesia, is now mixed with a strong solution of carbonate of potash or pearl-ashes, and sometimes with sulphate of potash, and allowed to stand till clear. The clear solution is then run off into boilers, and rapidly evaporated. During this process many of the impurities, such as common salt, chloride of potassium, sulphate and carbonate of lime deposit, and when the liquor in the boiler has reached a certain strength, it is drawn off into other large pans, and kept at a temperature of about 123° Fah., when a further crystallization of the impurities takes place. Finally it is run off into other vessels, allowed to cool, and the saltpetre then crystallizes. The impure crystals are

re-dissolved in water, boiled with glue to separate any organic matter, and, after filtration, placed in vessels, where the strong solution is constantly agitated with wooden stirrers to break up the large crystals and form only small ones, which shall retain the very smallest proportion of interstitial water.

One of the best tests for potash is the insoluble compound of cream of tartar or bitartrate of potash, which it forms with tartaric acid; it is also precipitated in conjunction with platinum, as the bichloride of platinum and chloride of potassium, $KCl,PtCl_2$, when bichloride of platinum and hydrochloric acid are added to a solution containing potash.

Fig. 252. Cutting down and burning Forest Trees, in order to collect the ashes for lixiviation, and manufacture of pearl-ashes or crude carbonate of potash; thus showing that potassium is characteristic of the land plants, as sodium is of the marine plants or sea-weeds.

Fig. 253. Portrait of Wollaston.

CHAPTER XXVIII.

PLATINUM.

PLATINUM is obtained from native platina, which occurs in obtuse-angled grains, with smooth, shining surfaces, and contains, besides platinum, also palladium, rhodium, iridium, osmium, iron, copper, likewise osm-iridium, and sometimes manganese. It was this complicated mineral which the great Dr. Wollaston attacked with his usual talent, and not only succeeded in eliminating platinum, but like-

wise all the other metals above named. The examination of this mineral offers one of the most interesting subjects of analysis that the advanced student of chemistry can possibly desire; and by consulting either the tables of Dr. Griffin, of Bristol, or those of Dr. Normandy, of London, he may master the principles upon which this examination may be successfully conducted.

The metal is usually obtained, by precipitating a solution of platinum in aqua regia (after separation from the other metals contained in native platina), by chloride of ammonium; a double chloride of ammonium and platinum is obtained, which is converted into a porous mass, called "spongy platinum," after being heated red-hot. The porous metal is gradually brought by compression into a compact brilliant white mass, which may be forged, welded, and hammered like iron, provided a sufficiently high temperature is employed. Platinum has the greatest specific gravity known—viz., 21·5; it is remarkably malleable, ductile, and tenacious, and is of the greatest value in the laboratory, being used in the manufacture of crucibles, spatulas, grain and fractions of a grain weights: and now that it can be melted and cast by the economical use of the intense heat of the oxyhydrogen blowpipe, no doubt many parts of the delicate mechanism of clocks and watches will be made with it. This metal is used for the nipples of rifles and other fire-arms, and is likewise employed, on account of its difficult fusibility, for the jet pieces of the oxyhydrogen blowpipe. Platinum stills, which may cost from 900*l.* to 1500*l.* pounds sterling, are employed in the final concentration of oil of vitriol.

The author's respected teacher, the late John Thomas Cooper, invented the platinum lustre for china, and formed an alloy of 1 part zinc, 16 copper, and 7 parts platinum, by fusing together under borax the copper and platinum, and finally adding the zinc, and well stirring the whole after its removal from the fire. This alloy is very ductile, is not readily attacked by nitric acid, and very much resembles in colour and weight pure gold.

If platinum and tinfoil are rolled together and held in the flame of a spirit-lamp, they alloy or unite instantaneously, with the production of a sudden flash of light and intense heat, which is very remarkable, and offers another illustration of the theory that metals unite chemically with each other in certain definite proportions.

Experiments with Platinum.

First Series.

The equivalent of platinum is 98·7, and it forms two oxides—viz., the protoxide, PtO, and the binoxide, PtO_2. This metal is not attacked by pure hydrochloric, sulphuric, or nitric acids, either hot or cold; but is readily dissolved by aqua regia, and if the solution is carefully evaporated with an excess of hydrochloric acid, leaves the bichloride of platinum, $PtCl_2$, which is converted into chloride, PtCl, when carefully heated at a temperature of 400° Fah., until no more chlorine is given off.

Second Series.

The mode of preparing spongy platinum has already been described. Platinum black is obtained by boiling a solution of the bichloride with sugar and carbonate of soda, constant agitation being used during the process. The black precipitate, after being thoroughly washed with boiling distilled water, may be dried spontaneously on blotting paper. When hydrogen gas is projected upon the spongy platinum or black, it takes fire in consequence of the condensation of the oxygen of the air in the pores of the metal, and its rapid union with the hydrogen in the presence of the platinum. The spongy platinum is usually mixed with pipeclay, and made into little balls, which, if placed in a cage of platinum wire and heated, may be used in the analysis of air by hydrogen, and being passed through the mercury of the mercurial trough into the tube containing the mixed gases, causes the oxygen and hydrogen to unite and form water.

Dobereiner's well-known hydrogen lamp has long been used as a rapid means of obtaining a light; and when the spongy platinum belonging to it refuses to act, it must be removed, boiled in nitric acid, thoroughly washed and gently heated, when it will again cause the hydrogen to take fire.

A platinum wire, turned in a spiral form, and placed over the wick of a spirit-lamp, will continue to glow after the flame is blown out; and if the lamp is fed with eau de Cologne or tincture of benzoin, and a little glass tube inserted in the wick, carrying a platinum wire supporting a ball of mixed spongy platinum or clay, it will continue to distil delightful odours into the room until the spirit is exhausted.

Third Series.

Platinum is precipitated from the state of bichloride by salts of ammonia and potash, forming yellow ammoniochloride of platinum, $NH_4ClPtCl_2$, and yellow potassiochloride of platinum, $KClPtCl_2$; hence the value of solutions of this metal in the detection and estimation of these important alkalies.

CHAPTER XXIX.

PALLADIUM, PELOPIUM.

PALLADIUM is one of the metals discovered and isolated by Dr. Wollaston in 1803, and is obtained from native platina by dissolving it in aqua regia, filtering, evaporating to a syrup, and adding water with cyanide of mercury, when a pale yellowish-white precipitate falls: this precipitate, washed, dried, and heated strongly, leaves a white matter, which is palladium. The metal, which is in a spongy state, is then worked into masses by pressure in the same manner as platinum.

Palladium is a hard metal of a white colour, and very malleable, ductile, and tenacious; it may be welded at a high temperature, and melts like platinum in the flame of the oxyhydrogen blowpipe: its specific gravity is 11·5, and equivalent number, 53·3. There are two oxides of palladium, the protoxide, PdO, and the binoxide, PdO_2; and although the mineral acids dissolve it slowly, aqua regia is the true solvent of this metal. Iodide of potassium precipitates a *black* iodide of palladium, and cyanide of mercury a yellowish-white precipitate of cyanide of palladium. The metal is used by dentists when alloyed with silver, and the author has seen graduated arcs of astronomical instruments and balances which were made of palladium, and likewise portions of chronometers.

Formerly the only source of palladium was the native platina already alluded to, but, as Mr. Cock has shown,*—

"Of late years, however, the importation into this country from Brazil of gold dust, alloyed with palladium, has occasioned a much more extensive supply of this metal, as it exists in some specimens of gold dust to the extent of five or six per cent., and in one instance (that of gold from the Candonga mine) it constitutes the only alloy of the gold.

"The operation of refining is conducted in the following manner. The gold dust is fused in charges of about 7 lbs. troy, with its own weight of silver, and a certain quantity of nitrate of potash; the effect of this fusion is to remove all earthy matter and the greater part of the base metal contained in the gold dust and in the silver melted with it. The fused mixture is cast into ingot moulds, and, when cooled, the flux or scoria (containing the oxides of the base metal, and the earthy matter, combined with the potash of the nitre) is detached. Two of the bars thus obtained are then remelted in a plumbago crucible, with such

* "Memoirs of the Chemical Society," vol. i. p. 161.

an addition of silver as will afford an alloy containing one-fourth its weight of pure gold, and which, being first well stirred to ensure a complete mixture, is poured through a perforated iron ladle into cold water, and thus very finely granulated; it is then ready for the process of parting. For this purpose about 25 lbs. of the granulated alloy is placed in a porcelain jar upon a heated sand-bath, and subjected to the action of about 25 lbs. of pure nitric acid, diluted with its own bulk of water. After the action of this quantity of acid, the parting of the gold is very nearly effected; but, to remove the last portion of silver, &c., about 9 or 10 lbs. of strong nitric acid are boiled with the gold for two hours. It is then completely refined, and after being washed with hot water, is dried and melted into bars containing 15 lbs. each.

"The nitrous acid gas, and the vapour of nitric acid, arising during the above process, are conducted by glass pipes (connected with the covers of the jars) into a long stoneware pipe, one end of which slopes downwards into a receiver for the condensed acid, the other end being inserted into the flue for the purpose of carrying off the uncondensed gas.

"The nitrate of silver and palladium obtained as above is carefully decanted into large pans, containing a sufficient quantity of solution of common salt to effect precipitation (as a chloride) of the whole of the silver, the palladium and copper remaining in solution in the mother liquor, which is drawn off, together with the subsequent washings from the chloride of silver, into wooden vessels; and the metallic contents are then separated, in the form of a black powder, by precipitation with sheet zinc, assisted by sulphuric acid.

"The chloride of silver, when washed clean, is reduced by the addition of granulated zinc, washed on the filter with boiling water, dried, and melted in plumbago crucibles without the addition of any flux. From the black powder obtained as above, the palladium is extracted by re-solution in nitric acid, and super-saturation with ammonia, by which the oxides of palladium and copper are first precipitated and then redissolved, while those of iron, lead, &c., remain insoluble. To the clear ammoniacal solution, muriatic acid is then added in excess, which occasions a copious precipitation of the yellow ammonio-chloride of palladium; from which, after sufficiently washing it with cold water, and ignition, pure metallic palladium is obtained. The mother liquor and washings contain all the copper and some palladium, which are recovered by precipitation with iron.

"Pure palladium is of a greyish-white colour, rather darker than that of platinum; it is both malleable and ductile, though inferior in those qualities to pure platinum; its specific gravity is 11·3, which may be raised by hammering or rolling to 11·8. When perfectly pure, it cannot be fused, even in small quantities, in an ordinary blast furnace, but may be brought into such a state of agglutination as to bear laminating or drawing into wire.

"It may be completely fused by means of oxygen gas, and being kept some time fused, is said to burn with the production of brilliant sparks.

It is not tarnished by exposure to sulphuretted hydrogen, nor oxidated by the air at the ordinary temperature, or at bright red heat; but it has the singular property of becoming oxidated by exposure to air at a dull red heat, the surface becoming coloured in the same manner as iron or steel; and by continuing the process cautiously for some time, the metal becomes coated with a brittle crust of oxide of a brown colour; this oxide is, however, reduced by a temperature very little higher than that necessary for its formation; and the surface of the metal regains its original colour upon being heated to a bright red, and cooled out of contact with the air.

"It is with difficulty soluble in nitric acid, when pure and fused, or in a state of aggregation; but is readily so when alloyed to some extent with silver or copper, and still more so when in the form of the black powder above referred to, in which state it is also soluble with the aid of heat in sulphuric and muriatic acids; but its proper solvent is nitro-muriatic acid, which, if it be not very much alloyed with silver, dissolves it readily.

"It is, of all the metals, that which has the greatest affinity for cyanogen; and by means of cyanide of mercury it may be separated from all its solutions. It may be alloyed so as to be malleable with gold, silver, and copper, several of its alloys with the two latter metals being of great use in the arts, from their hardness and elasticity, and non-liability to rust or tarnish. When added to gold or copper, it whitens both those metals in a very great degree, about 20 per cent. being sufficient in either case to destroy their colour. The uses to which the alloys of palladium have been applied are for the points of pencil-cases, for lancets for vaccination, for graduated scales of instruments, as a substitute for gold in dental surgery, or for any purpose where strength and elasticity, or property of not tarnishing, is required."

Pelopium has already been alluded to at p. 471, in connexion with the metals obtained from tantalite, and is not at present regarded with any interest, except by scientific chemists. It unites with oxygen, and forms a metallic acid, which contains three equivalents of oxygen, and is termed pelopic acid; this compound is said to be very like tantalic acid, and unites with other bases, forming pelopiates. By heating a mixture of pelopic acid and charcoal in a porcelain tube, and passing chlorine gas over them, the chloride of pelopium is obtained. The sulphide of pelopium may also be procured by heating pelopic acid in sulphuretted hydrogen gas.

CHAPTER XXX.

RHODIUM, RUTHENIUM.

RHODIUM is another of the metals discovered by Wollaston in 1804, and likewise obtained from native platina. It is very like platinum in appearance, is brittle, and so hard, that when used for the purpose of making the nibs of gold or silver pens, the lapidaries who grind it complain of the hardness as injurious to their working tools.

Rhodium has a specific gravity of 10·6, and its combining proportion is 52·2, and is remarkably infusible, being only rendered pasty by the oxyhydrogen blowpipe. There are two oxides—viz., the protoxide, RhO, and the sesquioxide, Rh_2O_3. It is not dissolved by the mineral acids, and even resists the powerful action of aqua regia, unless the rhodium is first alloyed with some other metal. The insolubility of rhodium in aqua regia and the effect of bisulphate of potash upon it, which is coloured pink, and attacks the metal, are to be considered as distinguishing characteristics of this metal.

Ruthenium was discovered by Professor Claus in 1845, and likewise exists in native platina; it is a very rare metal, and of no practical importance at present. Claus describes it as a blackish-grey powder, and calls it ruthenium because it occurs in small quantities in the white body described by Osann, which consists principally of silica, titanic acid, peroxide of iron, and zirconia, and was regarded by Osann as a peculiar metallic oxide, which he called the oxide of ruthenium.

Messrs. Abel and Bloxam point out a most interesting coincidence in the equivalents of the following metals just described.

First Group.

	Equivalent.
Platinum	98·7
Iridium	99·0
Osmium	99·6

Second Group.

Rhodium	52·2
Palladium	53·3
Ruthenium	52·2

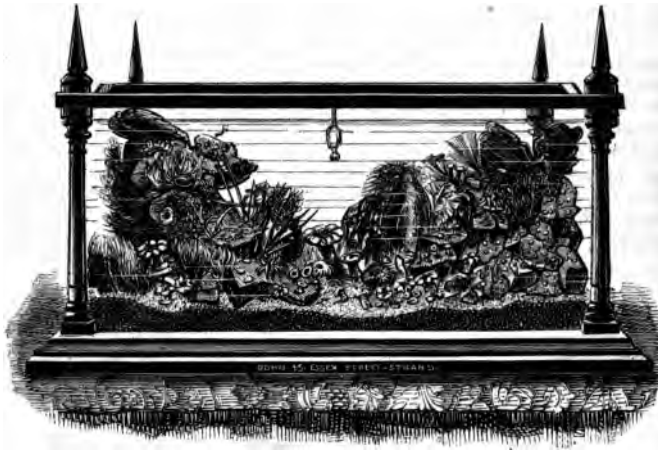


Fig. 254. A Sea-water Tank, or Vivarium, copied from one established by Bohn, Essex-street, Strand.

CHAPTER XXXI.

SODIUM.

In the chapter on silver, it has been shown that certain sea-weeds contain that metal: in the olden time, however, the sea-weed was collected by all the poor people of the parishes coasting Great Britain, when the ocean threw up its spoils (made in violent storms) from the otherwise tranquil meadows of sea-weed. Protected by one of Heinke's diving dresses, and supplied with air, even human beings might observe for themselves the appearance of a world, full fathom deep, to which the drowned mariner only pays his last solemn visit. But this inquisition is more safely arrived at by gazing into the little pools of water and sea-weeds left by the receding tide, or at home in the aqua vivaria. It should have been stated that the sea-weed was collected and burnt, and produced an ash called "barilla," which, lixiviated with water, afforded carbonate of soda, known familiarly to all who pay their weekly domestic bills by the name of washing soda.

Sodium was discovered by Davy in 1807, and is procured much in the same manner as potassium. The carbonate of soda is mixed with acetate of soda and calcined; the charcoal from the decomposed acetate

is thus distributed through the mass, which is powdered, mixed with small lumps of charcoal, and subjected to heat in a wrought-iron bottle. The metal distils over much more easily than potassium, and is now prepared in large quantities for the preparation of the new metal aluminium.

Sodium is a white metal like silver, extremely soft, so that it is easily squeezed and moulded in the fingers, or cut with a knife; its specific gravity is 0·97 and combining equivalent 23. Potassium is pasty at 70° and liquid at 137°, whilst sodium does not become perfectly fluid until it reaches a temperature of 194° Fah. Potassium takes fire directly it touches the surface of water contained in any convenient vessel. Sodium appears to cool too rapidly in a large quantity of water, but takes fire easily on well wetted blotting-paper. If an inclined plane is made with a board a few feet in length, provided with a ledge on each side, and wet blotting-paper laid upon it (Fig. 255), the sodium

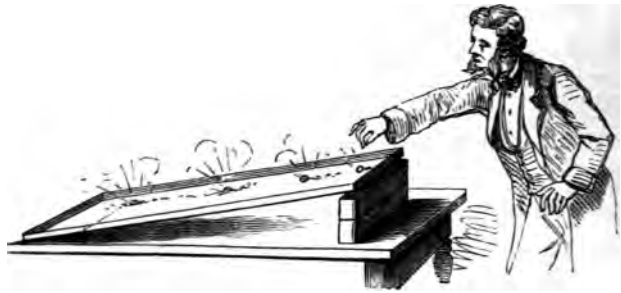


Fig. 255. Globules of Sodium rolling down and burning on the wet Blotting-paper placed on an Inclined Board provided with ledges at the sides to prevent the Metal rolling off.

launched at the top rolls down the miniature hill, and, taking fire, presents a most curious appearance, burning during the time of its descent with an intense yellow light. In all experiments with potassium and soda on water, care must be taken to avoid the final bursting of the red-hot spheroid of potash or soda, which offers another illustration of Boutigny's discoveries.

Sodium forms two, perhaps three, oxides—viz., soda (NaO), teroxide of sodium (NaO_3); and possibly a suboxide.

Soda is produced whenever sodium is burnt on water; and as it is required in large quantities for commercial purposes, and especially in soap-boiling, it is usually made by boiling together, in a cast-iron pan, three parts of common crystallized carbonate of soda, fifteen of water, and one of lime slaked with three of water. This metal, like potassium, forms the most valuable salts, of which common salt (easily made by burning sodium in chlorine gas), carbonate of soda, hyposulphide of soda, sulphate of soda, phosphate of soda, are important examples: in

fact, the manufacture of soda for glass and soap making, and as a detergent, is second only in importance with that of iron; and is one of those staple products of industry of which commercial England may be justly proud. Soda is now made by decomposing common salt; but formerly it was wholly obtained by burning sea-weed, and collecting and lixiviating the ashes. The product was called barilla when it came from Spain; kelp, when made on the coasts of England, Scotland, Ireland, and Wales.

Soda is precipitated in a white crystalline state in combination with antimonic acid (SbO_5) as the antimoniate of soda (NaO,SbO_5), provided the solution containing it is slightly alkaline. This test, however, can only be relied on in the absence of all other oxides.

Periodate of potash (KO,Io_7) likewise forms a white precipitate in concentrated solutions of soda.

The most characteristic test of the presence of sodium is a spirit flame, which is immediately changed to a yellow light if a piece of paper moistened with the solution supposed to contain soda is dried and then allowed to burn in contact with it; and still better if the smoke from the burning paper is passed up into a wire gauze chimney whilst the mixed coal gas and air are burning.

As common salt (chloride of sodium) is not only the speciality of the ocean, but is found in all the secretions of the human body, it is considered the characteristic of the animal, just as potassium is thought to represent the vegetable kingdom: at all events, the idea is a good one, and assists the memory in recollecting the sources of these two most valuable alkalies.

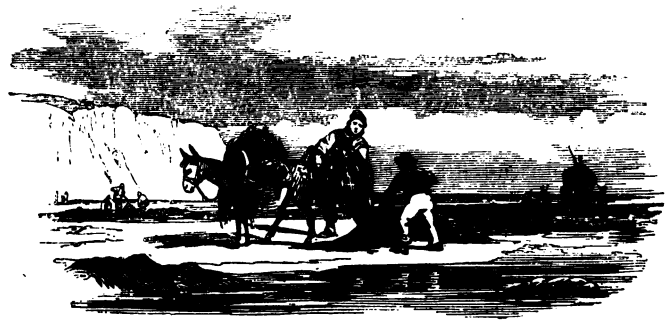


Fig. 256. Collecting and burning Sea-weed on the Sea-shore for the Manufacture of Kelp.

Fig. 257. People looking at Fireworks. "Oh!—O——h!!!"

CHAPTER XXXII.

STRONTIUM.

Our picture demonstrates the chief use of this salt by pyrotechnists, for the purpose of producing those fiery effects which excite and draw forth so many admiring and long-sustained "O—hs!" from the British public.

The metal was proved to exist by the triumphant Davy in 1808, and is obtained from a mineral which was brought, in 1787, to Edinburgh, by a dealer in fossils, from the lead mines of Strontian in Argyleshire. Klaproth christened the new earth strontian, which is a natural carbonate of strontium, found abundantly in various parts of the world. It yields a metal by the same process as that described for barium, p. 435: it is stated to be white, solid, heavier than water, and presents very much the same physical characters as barium. Dr. Matthiessen has, however,

shown, in his paper on the preparation of strontium and magnesium*—"that strontium resembles calcium in colour (a light yellow, like that of gold alloyed with silver), being only a shade darker. It oxidizes much more quickly than that metal. The specific gravity of the metal obtained from pure chloride of strontium gave, in two experiments, 2·5041 and 2·5796; the mean of which is 2·5418. Its atomic volume is 216, being one and a half greater than that of calcium. The specific gravity of calcium from pure chloride of calcium gave, in three experiments, a mean of 1·5778, and its atomic volume is 158. Strontium burns like calcium, and also acts similarly to it when heated in chlorine, oxygen, bromine, or iodine, or on boiling sulphur, or when thrown into water or acids. The best method, by which pieces weighing half a gramme are sometimes obtained, is as follows:—A small crucible, with a porous cell, is filled with the anhydrous chloride of strontium, mixed with some chloride of ammonium, so that the level of the fused chloride in the cell is much higher than in the crucible. The negative pole placed in the cell consists of a very fine iron wire wound round a thicker one, and then covered with a piece of tobacco-pipe stem, so that only about the one-sixteenth part of an inch appears below; the positive is an iron cylinder placed in the crucible round the cell. It is easy to regulate the heat during the experiment, so that a crust may form in the cell; the metal will then collect under this crust, without coming in contact with the sides." Dr. Matthiessen states that he has found this method very advantageous also for the preparation of calcium.

Strontia unites with oxygen in two proportions, forming strontia (SrO), and binoxide of strontia (SrO_2).

Strontia forms with nitric acid the nitrate of strontia, which is the salt employed in pyrotechnic compositions; and as the proportions for red fire are given in the "Playbook of Science," they need not be repeated here.

Both strontian and baryta are detected when in solution by sulphuric acid, which forms with these earths sulphates insoluble in acids and alkalies.

Strontium is distinguished from baryta by the carmine-red colour it imparts to a spirit or diluted gas flame. Baryta affords a green colour.

Hydrofluosilicic acid ($3HF,2SiF_3$) does not precipitate strontian, and therefore serves, like the flame test, to distinguish it from baryta, which forms with this acid a white precipitate that gradually becomes crystalline.

* "Quarterly Journal of the Chemical Society," vol. viii. p. 107.

Fig. 258. The Alchemist, the Model of patient Investigation.

CHAPTER XXXIII.

TANTALUM, TELLURIUM, TERBIUM, THORIUM, TITANIUM.

TANTALUM is obtained from tantalite, a mineral which occurs in Finland, and contains, according to the analysis of Berzelius—

Tantalic acid	83·2
Protoxide of iron	7·2
Protoxide of manganese . . .	7·4
Oxide of tin	0·6
Loss	1·6
	100·0

It was from the tantalic acid, stated in the above analysis, that Rose obtained niobic and pelopic acids, the oxides of two new metals already mentioned.

Tellurium.—The properties of this metal are fully known and described; and in 1798 Klaproth gave it the name of tellurium, which had been called by Kirwan, in 1796, sylvanite. The mineral from which it is obtained is called tellurite, and consists, according to Klaproth, of—

Tellurium	92·55
Gold	0·25
Iron	7·2
	100·00

The metal is silvery white and brilliant; it has very much the appearance of antimony, being extremely brittle, and easily reduced to powder. Its specific gravity is 6·2, and equivalent 64·2, and it forms with oxygen, tellurous acid (TeO) and telluric acid (TeO_3).

Terbium has already been mentioned at p. 454, in connexion with erbium, and is found in gadolinite.

Thorium, or *thorinum*, is a metallic curiosity, and found in thorite. This mineral, according to Berzelius, consists of—

The oxide of thorium, thorina	57·91
Silica	18·98
Lime	2·58
Peroxide of iron	3·40
Peroxide of manganese	2·39
Magnesia	0·36
Oxide of uranium	1·61
Oxide of lead	0·80
Oxide of tin	0·01
Potash	0·14
Soda	0·1
Alumina	0·06
Water	9·5
Undissolved mineral	1·7
Loss	·46
	100·00

Titanium, another rare metal discovered by Klaproth, and found, in conjunction with iron, in certain iron ores, especially in rutile, which contains about 60 per cent. of titanium. It forms three oxides, viz.—

Oxide of titanium	TiO
Sesquioxide	Ti_2O_3
Titanic acid	TiO_2

and is described as a dark green powder, which burns vividly in the air or oxygen, and forms titanic acid.

Fig. 259. "Prevention is better than Cure."

CHAPTER XXXIV.

TUNGSTEN.

THIS metal is so called from a Swedish mineral called tungsten, or *ponderous stone*. The industrious Scheele discovered the tungstic acid in 1781, but D'Elhuyart first procured it in the metallic state by mixing the acid substance obtained from wolfram (a mineral already alluded to in connexion with tin ores) with powdered charcoal, and exposing it to a very intense heat.

Berzelius calls tungsten "wolfranium." It is a greyish-white metal

like steel, and possesses considerable brilliancy. It possesses a remarkable hardness, and has lately been applied with success by Mr. Oxland, of Plymouth, in the manufacture of the hardest steel, which, it is said, will bore through and file ordinary steel, so that, if England is to begin a course of experiments on the best armour for ships, Mr. Oxland should be consulted on this most important question.

The specific gravity of tungsten is 17·6, and its equivalent 95. It forms with oxygen gas two combinations:—

Binoxide of tungsten	WO_2
Tungstic acid	WO_3

Wolfram is obtained abundantly in Cornwall, and was formerly considered to be worthless; but since Oxland has discovered a mode of separating the tin, and is now likely to employ the tungstic acid, we may shortly expect to see the price of wolfram take a respectable position in the metallic market. Wolfram is a tungstate of iron, and consists of—

Tungstic acid	78·77
Protoxide of iron	18·32
Protoxide of manganese	6·22
Silica	1·25

The above analysis of Berzelius is evidently incorrect, but still affords a good notion of the quantities of the various ingredients.

This and other analyses show that wolfram is a double tungstate of iron and manganese, $(FeMn)O+WO_3$. Tungstic acid is employed in the preparation of tungstate of lead, which is said to be valuable as a white pigment, and capable of being used for all the purposes to which ordinary white-lead is applied.

In order to prepare tungstic acid, wolfram is digested with aqua regia, which dissolves out the iron and manganese, and leaves the tungstic acid; the latter is then well washed, and heated with ammonia. This alkali unites with the tungstic acid, and as the tungstate of ammonium is soluble in water, the latter is easily separated from the remaining silica or sand. By heating the tungstate of ammonium in air, tungstic acid is procured, which has a straw-yellow colour, and is insoluble in water and acids.

Tungstic acid is united with soda, and is used not only in calico printing, but is found to be one of the best and cheapest anti-combustible salts ever applied to textile fabrics, and, indeed, is now employed, in conjunction with starch, in the royal laundry.

Fig. 260. Warrington's Microscope, an instrument of great value in analytical investigations.

CHAPTER XXXV.

URANIUM, VANADIUM, YTTRIUM.

URANIUM deserves special notice, because, although a rare metal, its oxide is employed most usefully for colouring glass of a peculiar yellow colour, having certain curious optical characteristics, as shown by Professor Stokes of Cambridge. It is likewise employed in porcelain painting. The name of this metal is derived from that of the planet "Uranus," and it is procured in the state of oxide from "pitchblende,"

which is found in Cornwall, and also in Saxony and Bohemia. Thomson's process for procuring pure protoxide of uranium is thus described by him: "Pitchblende is reduced to a fine powder, and digested with nitric acid until everything soluble in that acid is removed. The solution is then rendered as neutral as possible by evaporation, and a current of sulphuretted hydrogen gas passed through it as long as any precipitate continues to fall. The liquid is then filtered and heated to drive off all traces of sulphuretted hydrogen. It is now precipitated by caustic ammonia, and the precipitate, after being well washed, is digested, whilst still moist, in a pretty strong solution of carbonate of ammonia. A fine lemon-coloured liquid is thus obtained, which, being set on one side for a few days, deposits abundance of fine yellow crystals, in four-sided right prisms with rectangular bases. These crystals, being exposed to a red heat, give out water and carbonate of ammonia with oxygen gas, and leave the protoxide of uranium in the state of a black powder, having a good deal of lustre, but which, when reduced to powder, presents a dark green colour." The yellow crystals consist of

3 atoms	carbonate of ammonia	14·625
1 „	percarbonate of uranium . . .	30·75
4 „	water	4·5
		49·875

The specific gravity of uranium is 8·1, and its equivalent 60, and the metal unites with oxygen in three proportions, viz.:—

The suboxide of uranium	U_4O_3
The protoxide of uranium	UO
The peroxide of uranium	U_2O_3

Vanadium was discovered by Sefström, who called it after one of the ancient female deities of Scandinavia. It is, of course, a rare metal, and resembles chromium, molybdenum, and tungsten; the metal is like chromium, because it imparts a green colour to blowpipe fluxes. It also forms a red acid, vanadic (VO_3); but, whilst chromic acid retains its colour on evaporation from its solution, vanadic changes by heat, becomes colourless, and deposits vanadic acid in the form of a deep red powder. The metal was first obtained from certain specimens of Swedish iron, which were remarkable for their malleability, and was afterwards procured in larger quantity from scoriæ of the furnace where the iron had been melted. The equivalent of vanadium is 68·6, and it resembles molybdenum in the blue colour of certain of its combinations. Vanadium has been obtained from certain lead ores; and there are three oxygen compounds, viz., the protoxide (VO), the binoxide (VO_2), and vanadic acid (VO_3).

Yttrium is another rare metal, first discovered in Jenny Lind's country, at Ytterby, in Sweden, by Captain Arbenius, in 1788. Gadolin, Vauquelin, and Klaproth all examined the new earth, which they called yttria, being an oxide of the metal yttrium, and combined with gadolinite, already described at p. 454, and named after Professor Gadolin.

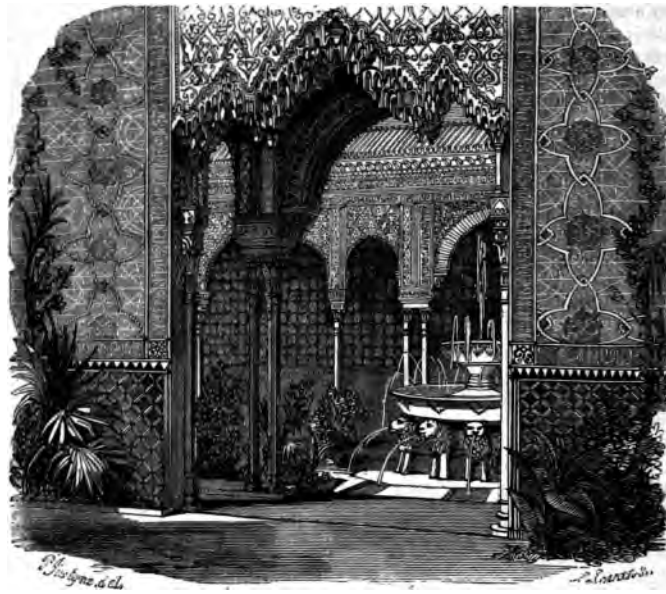


Fig. 261. The Court of Lions.

CHAPTER XXXVI.

ZINC.

This metal was not known to the ancients, although they were acquainted with the mineral cadmium or calamine; and without it they could not have made brass, which alloy of zinc and copper is repeatedly mentioned in the Scriptures; and its use in Solomon's temple, in the construction of the sea of brass supported on the backs of twelve oxen, no doubt suggested the beautiful Moorish fountain of lions of the ancient Alhambra, a copy of which adorns the lovely and unique Alhambra Court of the Crystal Palace. Hesiod states that "in remote ages the earth was tilled with brass implements of agriculture, because iron had not been discovered."

Zinc appears to have been first called by that name in the writings of the madly-zealous Paracelsus, about the year 1540. It is supposed that

the term is derived from the Teutonic "zinken," signifying *nails*, because the metal, when poured in the liquid state into cold water (Fig. 265), assumes the form of a number of jagged and pointed fragments, not very much like nails, but perhaps sufficiently so for the fervid imagination of the bombastic Paracelsus, who also termed calamine the spurious son of copper. This divided condition of the metal is familiarly known to every tyro of the art as "granulated zinc." Lewery termed zinc a kind of bismuth. Glauber imagined it to be an immature "solar sulphur." Homberg said it was a mixture of tin and iron. Kunckel (of phosphorus celebrity) declared it to be coagulated mercury. Schluter imagined it to be tin made brittle with sulphur.

Pettus, in 1686, says "It is a great error that most writers run into, by promiscuously giving the title *Æs* for both *Brass* and *Copper*, as if they were the same metals; whereas *Æs* or *Brass* is not a proper *Metal*, but compounded of a *Metal*, viz.: *Cupreum* or *Copper*, and '*Lapis Calaminaris*' or *Cadmiæ*, which is a *Mineral*, and from the mixture of these two *Brass* is made. . . . Now, whereas *Pliny* (cap. 33) speaks of about eighteen several *Mines* of *Brass*, we must not understand it as a specifick *Metal*, though the word Æs is vulgarly applied to both; but those *Mines* were either *Copper Mines* capable of being made *Brass*, or so many several sorts of *Lapis Cadmiæ* or *Calamine*, from the composition of all which with *Copper*, *Brass* was made, more or less, both in *Quantity* and *Quality*. And this art of composing it is said by him to be first invented by *Cadmus*, a *Grecian* contemporary with *Joshua*, in whose time the word Brass is first mentioned in the *Sacred Story*, Exod. xxv. 3. And it is observable that though, in the composition of *Brass* there is more of the *Stone* than of the *Copper*, and that *Copper* is a *Metal*, and that other a *Stone*, yet it takes a new name of *Brass*, and not its own, or of the *Metal*, *Copper*; and being thus made *Brass*, it is an *Imitation* of *Gold*, both in *Colour* and in many *Virtues*, and in such esteem that the *Roman* Treasurers were called '*Tribuni Ærarii*,' rather than *Aurarii*. And *Camerarius* says that the *Egyptians* (long before the *Romans*) had so great Veneration of *Brass*, that they made *Images* of it, and laid them in the graves of their *Kings*, to preserve their *Bodies* from putrefaction; and to men of lesser quality they nailed their dead bodies with many *Brass* nails. Also *Virgil*, *Horace*, and *Homer* are all full of their *Encomiums* on *Brass*, and therefore it may well have the honour of a seventh metal, though compounded of a mineral."

The metal zinc is first mentioned, about the thirteenth century, in the writings of Albertus Magnus, under the name of the marcasite of gold; and it is evident, from his account of it, that he was aware that a volatile metal existed in the alloy. The use of calamine in the composition of brass was known to Aristotle, who makes a distinction between the compound resulting from the mixture of copper and calamine and that resulting from the mixture of copper and tin.

The ancients were acquainted with the fact that when cadmia was burnt it changed into a white, flocculent, and spongy ash, that volatilized, and which they employed in medicine. There are strong

reasons for believing that it was known at a very early period in China. The Chinese were acquainted with the method of rendering it malleable, and they struck pieces of money of it, having the Tartar characters on one side and Chinese characters on the other. Kasimir, the Pliny of the Arabians, at least states these circumstances as facts. The Arabians called it *Rouh-tutia*, and the Persians *Kar-tsini* (Chinese iron). According to Kasimir, "mirrors were made of it, which were considered as useful in curing sore eyes." No ancient coins or implements made of zinc have been discovered in Europe; and it was not till the beginning of the eighteenth century that any processes were described for its production. Dr. Isaac Lawson is said to have been the discoverer of the process of distilling zinc from the ores, of which two are chiefly employed for that purpose, viz.: the carbonate of zinc or calamine, and the sulphide called "blende," or "blackjack." There are other important ores, especially the red zinc ore, or red oxide of zinc; and in the Great Exhibition of 1851 an enormous mass of the latter ore was deposited, weighing 16,400 pounds. The following are the names and constituents of the zinc ores :—

Name.	Constituents.
The red zinc ore, or red oxide of zinc	Zinc, oxygen, with some oxide of iron and red oxide of manganese, which are supposed to be the cause of the red colour of the mineral.
The sulphide of zinc; yellow, brown, and black, blende, or blackjack	Contains zinc, sulphur, and sometimes a little iron, fluorine, silica, and water, arsenic, cadmium, lead, and copper.
The carbonate of zinc, calamine, zinnespath, lapis calaminaris	Oxide of zinc and carbonic acid and water.
Silicate of zinc, or electric calamine	Oxide of zinc, silica, and water.

The ores of zinc are discovered in the carboniferous or mountain limestone, and in the magnesian limestone, or alpine limestone, and are associated in nature most frequently with galena or sulphuret of lead, copper pyrites, copper green, and iron pyrites; and the mining operations already explained in connexion with the latter mineral will also serve to indicate the manner in which these zinc ores are procured.

Blackjack, or sulphide of zinc, is obtained in abundance in Cornwall, Cumberland, and Derbyshire, and, in the absence of foreign zinc, would doubtless be extensively reduced; but at the present time the celebrated foreign company at the Vieille Montagne, near Liége, with others, compete so successfully with British zinc, that it hardly pays to reduce the ores. At Sheffield, Bristol, and Birmingham especially, the toy-shop of the world, where so many brass articles are made, calamine is reduced to the metallic state. The process is comparatively simple, and consists in first carefully hand-picking the ore to remove the galena, and then calcining it in a reverberatory furnace, or rather oven. The roasted ore, deprived of carbonic acid, water, and sulphur, as the case

may be, is then mixed with charcoal alone if prepared from calamine; but if from blende, a certain quantity of roasted calamine is also added, and the whole placed in earthen pots, or crucibles, very much like the pots used at glass works, but provided with a luted cover and also with an opening at the bottom, to which an iron pipe is fitted. After the heat has been applied sufficiently long, the volatile metals, such as arsenic and cadmium, make their way in vapour, *per descensum*, to the end of the iron tube, where they afford a flame, which the workmen distinguish by the name of the *brown blaze;* this is succeeded by a blue flame, called the *blue blaze*, which indicates the distillation of the zinc; and then the metal is condensed in the iron tube, and falls in drops and in a powdery state into a vessel placed to receive it; as may be easily imagined, the iron pipe sometimes becomes stopped, and is occasionally cleaned by a red-hot iron rod.

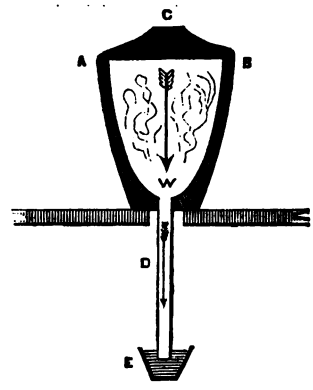


Fig. 262. A B. Large earthen crucible or pot containing a mixture of roasted zinc ore and coal or charcoal. C. The cover closely luted down. D. The iron pipe in which the zinc vapour condenses and falls into the vessel E, containing enough water to cover the end of the pipe. The pipe is removed after each charge has been exhausted, in order to take out the caput mortuum or matter left in the crucible after distillation. The arrows show the direction of the metallic vapour, and the iron pipe is usually plugged with wood, W, which is soon reduced to charcoal, and whilst preventing the ore from falling out, does not stop the zinc vapour.

Although it is not the first example of the distillation of a metal we have had to notice, still the process of reduction by charcoal and distillation *per descensum* (or in the reverse position of that usually taken by the still head in the distillation of alcohol) is very interesting, and affords another example of the intimate relations existing between solids, liquids, and gases, and it also assists the mind in surmounting the difficult process of reasoning required by unscientific thinkers when they endeavour to connect the permanent gaseous element hydrogen with the solid metals, because the ideas generally associated with a gas and a metal are so very far apart from each other; but when the chemical facts are examined in detail, these apparent differences vanish by gradually merging one into the other.

It is not, however, difficult to remember that the zinc chimney-pots which help to convey away the gases from our fireplaces have themselves once been in the state of vapour whilst being released from their mineralized state by the deoxidizing power of heated carbon. The crude distilled zinc is finally melted in large iron pots, and, after being well skimmed, is cast into ingots. At the Vieille Montaigne works, larger retorts, furnaces, and arrangements are employed for the distil-

lation of the zinc, which, it might be imagined, could be readily imitated and worked at a profit in England.

Zinc is a brilliant white metal having a slight tinge of blue, and a specific gravity that varies from 6·861 to 7·1. The discovery of the increase of its malleability at a temperature of about 212° Fah. has greatly enhanced its value, and if the metal did not become soft and malleable at that temperature, many articles now manufactured could not be made, as it would break in the attempt to form it into shapes, when it has to be hammered and bent at very sharp angles. Amateurs who make voltaic batteries are sadly teazed with the hardness of zinc until they learn that it can be easily bent, after being warmed to the proper temperature, which is generally discovered by wetting the finger and tapping it on the zinc: if the water evaporates at once with the usual fizzing noise, the operation of bending may be commenced without fear of breaking the zinc. There is, however, a limit to the increase of malleability on the application of heat, and at 400° Fah., zinc becomes so brittle that it can be easily powdered in a mortar; at 680° Fah. it melts, and at a still higher temperature, volatilizes, and may be easily distilled, provided the access of air is prevented.

Zinc, like many other metals, if allowed to cool slowly and in sufficient quantity, crystallizes in prisms with six-sided bases, reminding one of the basaltic columns of the Giants' Causeway.

Fig. 263. Zinc Chimney-pots.

The use of zinc to alloy with copper and form *brass* has been already alluded to; there are also other important alloys, such as *pinchbeck*, which consists of five or six parts of copper and one of zinc; tombac, prince's metal, and other arbitrary mixtures of the two metals, which are further described in the chapter on copper.

The tenacity of zinc is very moderate, but probably increases with a temperature of about 216° Fah. It is employed for covering the roofs and lining the gutters of houses instead of lead, which is, of course, considered a very false economy by builders, unless the houses are built *to be sold;* because during the winter the zinc becomes harsh and somewhat brittle,

and should the wind find its way under the zinc, the house roof is soon stripped of its covering, or so bent and broken in parts, that the whole must be renewed. Baths, window sashes, trade signs, frames of aqua vivaria, and all kinds of ornamental work are constructed of this metal, of which, perhaps, the least decorative are the chimney-pots, so expressively delineated by *Punch* in his funny sketches.

Experiments with Zinc.

First Series.

The assay of an ore of zinc by the dry method presents many difficulties in the way of a correct estimation of the metal, in consequence of the volatility of zinc; it is, therefore, usual to perform the assay by the wet process: thus, if calamine is the ore under examination, it may be roughly assayed by the following process. A weighed quantity is first heated in a short hard German green glass tube, to which a weighed tube filled with chloride of calcium or pumice-stone soaked in oil of vitriol is attached, for the purpose of determining the per-centage of water by the increase of weight in the latter tube.

Another weighed quantity is then strongly heated in a porcelain crucible, and the loss represents the carbonic acid and water contained in the mineral, and by deducting the weight of water obtained by the tube experiment, the per-centage of two of the constituents—viz., water and carbonic acid—are discovered. The roasted ore is now dissolved in nitro-hydrochloric acid, evaporated to dryness, and the soluble salts washed out, whilst the insoluble portion may be collected, washed, dried and ignited, and they represent the silica.

The solution containing the soluble salts is precipitated by ammonia in excess, and, being filtered, is evaporated to dryness with an excess of carbonate of soda, again dissolved in water, the carbonate of zinc collected on a filter, washed, dried, ignited, and estimated as oxide of zinc. Various refinements on the above must be used if an exact analysis is required.

Second Series.

The equivalent of zinc is 32·6, and it combines with oxygen in three proportions, forming the

Suboxide of zinc	Zn_2O
Protoxide of zinc	ZnO
Peroxide of zinc	ZnO_2

The existence of the suboxide has rather been inferred from analogy, and it is supposed to be formed when a bright metallic surface of zinc is exposed for some time to the action of air and moisture.

The oxide of zinc (ZnO) appears to have been known to the ancients, who called it *pompholyx*. It is easily prepared by setting fire to a bundle of zinc turnings arranged in an ornamental iron-wire basket (used for suspending flower-pots), and having a little tow saturated with spirits

Fig. 264. A B. Iron-wire basket containing the zinc turnings, and having a very little tow at the bottom saturated with spirits of wine. C. The lighted torch for igniting the tow at bottom of the basket. The falling particles indicate the oxide of zinc.

of wine at the bottom for the purpose of kindling the metal. As the metal burns it produces a large quantity of very flocculent oxide of zinc, which floats about the air of the room, and was called by the ancients and the alchemists the "philosopher's wool"—flowers of zinc. Dioscorides, who lived in the second century of the Christian era, was the first who compared it to wool.

The oxide of zinc formed in this manner is anhydrous; and it may also be prepared by melting some zinc in a red-hot crucible, and then throwing in a little nitre, which, affording oxygen, produces (when stirred into the melted zinc) a most brilliant deflagration of the metal. Some zinc filings mixed with powdered chlorate of potash will also easily take fire on the application of a lighted taper. When steam is passed over zinc at a dull red heat, it is rapidly decomposed into its elements, hydrogen escapes in large quantity, whilst the oxygen unites with the metal and forms the oxide of zinc. Such is the affinity of zinc for oxygen, that the decomposition of steam will commence even when the zinc is only heated to 212° Fah., provided it is in a sufficiently divided state. Zinc dissolves in fused potash with astonishing rapidity, being oxidized at the expense of the alkali, and apparently combining, like an acid, with the excess of potash. Pure oxide of zinc, when heated, becomes yellow, but changes to white after being cooled; it is extensively used as a pigment under the name of *zinc white*, which has certain advantages, viz., that it does not produce those distressing effects of colic on the system which are provoked by the use of lead paint, and does not turn black by the sulphuretted hydrogen gas so frequently prevalent in large towns where coal gas is made.

When diluted sulphuric acid is poured on zinc, the water is decomposed, and the hydrogen escapes, as in the process of making that gas so fully described in the "Playbook of Science," p. 107. The

oxide of zinc unites with the sulphuric acid, and forms the well known salt called sulphate of zinc or white vitriol (ZnO,SO_3), which is prepared in the pure state by dissolving some ordinary zinc in dilute sulphuric acid, and, after placing it in a large wide-mouthed bottle, some chlorine may be poured in, and the whole well shaken, taking care to prevent the stopper being fixed in through the vacuum formed, by introducing a very fine thread, so that the stopper does not quite fit the neck of the bottle, and permits the entry of the air. The object of the chlorine is to convert any iron present to the state of peroxide, which is precipitated when the solution is heated with a little excess of pure carbonate of zinc. Subsequent filtration and careful evaporation will yield crystals of pure sulphate of zinc. Native sulphate of zinc occurs at Holywell, in Flintshire. Dr. Thomson denies the formation of the binoxide of zinc (ZnO_2) by Thenard's process, and considers it to be only a mixture of deutoxide of hydrogen and oxide of zinc. A very distinguishing test for the oxide of zinc is a drop of a solution of nitrate of cobalt, which, being dried and ignited with the oxide, becomes of a green colour.

Third Series.

Chloride, iodine, bromine, and fluorine all unite with zinc; and of these the most important is the chloride (ZnCl), which is prepared by dissolving zinc in pure hydrochloric acid, heating the liquid with excess of chlorine and carbonate of zinc, and, after filtration, finally evaporating and fusing in a thin porcelain dish. Chloride of zinc forms beautiful white lumps, that quickly deliquesce and dissolve very readily in water, forming Sir W. Burnett's disinfecting fluid, which is sometimes employed to delay the putrefaction of the subjects used for dissection. The chief value of this disinfecting fluid is due to its power of absorbing sulphuretted hydrogen; but it has neither the deoxidizing power of sulphurous acid, or the oxidizing power of chlorine or manganic acid. There are both oxychlorides and oxysulphides of zinc. And the chloride of zinc may also be prepared by dropping zinc filings into chlorine gas. Solutions of salt must not be kept in vessels lined with zinc; and the author remembers a case where some brine used in pickling beef, and kept with the latter in a zinc cistern or vat, contained a considerable portion of chloride of zinc, which is a poisonous salt. When obtained by distilling a mixture of corrosive sublimate and zinc filings, it was distinguished by the alchemists as the "butter of zinc."

Fourth Series.

Zinc is detected by the following tests:—

Sulphuretted hydrogen precipitates the white sulphide of zinc (ZnS), in part from perfectly neutral solutions of zinc, but affords no precipitate in acid solutions, unless they are weak acids, such as acetic acid. If an excess of acetate of soda is added to a neutral solution of zinc, the whole of the metal may then be precipitated by sulphuretted hydrogen as the sulphide of zinc.

Sulphide of ammonium precipitates the sulphide of zinc from neutral and alkaline solutions insoluble in an excess of the reagent, or caustic potash, or solution of ammonium, but soluble in acids. This is the most characteristic test for zinc; and any strong, colourless, alkaline solution, producing a white precipitate with a soluble sulphide, and extremely difficult to filter, may be pronounced to contain zinc with almost unerring certainty.

Solutions of potash and ammonium precipitate the hydrated oxide of zinc, which is soluble in an excess of the precipitate.

A solution of carbonate of ammonia throws down a hydrated carbonate of zinc, soluble in an excess.

Carbonate of soda, in the absence of salts of ammonia, precipitates the carbonate of zinc, insoluble in an excess. A drop of a solution of nitrate of cobalt placed on oxide of zinc, and ignited, affords an emerald-green colour.

Fig. 265. Process of granulating Zinc by pouring it from a height into a pail of cold water.

CHAPTER XXXVII.

ZIRCONIUM.

Among the precious stones exhibited by Hunt and Roskell, of Bond-street, at the first palace in Hyde-park, were some magnificent specimens of the jewel called zircon, or jargon, or jargoon, of which one deserves special comment, being a superlatively fine jargon, of an octagonal form, cut with step facets, of a very fine deep orange colour of the purest tint, having the charming hue, prismatic play, and brilliancy of the diamond. At the time it was considered that it would be a difficult task to match this beautiful gem, on account of its extraordinary fine and unique colour. The hardness of this gem is, however, inferior to that of the sapphire, one of the lovely forms assumed by alumina; but it is greater than that of the spinel ruby, its specific gravity being 4·416 to 4·7. Klaproth analysed it in 1789, and discovered therein a new earth, which he termed zirconium. Berzelius, in 1824, was the first to obtain the metal from the oxide of zirconium, or zirconia, from the potash fluate of zirconia; and the impure metal is stated to have a close resemblance to charcoal dust, and does not assume any brilliancy even after being rubbed with a burnisher. When purified, zirconium is like plumbago. It is composed of brilliant scales, and is stated to be an exception to one of the special properties of the metals in being a non-conductor of electricity. Zirconia (Zr_2O_3) is the only compound of this metal with oxygen known at present; and its metallic qualities, as above stated, ought to be received with some reservation, considering that it has not yet, like aluminium, been cast into bars or lumps, and therefore its mechanical characteristics can hardly be described.

CHAPTER XXXVIII.

GENERAL REMARKS.

In the preceding chapters the metals have been described alphabetically, with the exception of those which were known to the ancients. This arrangement was adopted to facilitate reference; but one of the best classifications is probably that of Gmelin, who arranges the metals as follows:—

I. *Light Metals.*

A. Alkali metals . . .	Potassium, sodium, lithium, barium, strontium, calcium.
B. Earth metals. . . .	Magnesium, cerium, lanthanium, didymium, yttrium, erbium, terbium, glucinum, aluminium, thorium, silicium, zirconium.

II. *Heavy Metals.*

C. Base metals not reducible by heat alone, brittle, and also difficultly fusible . . .	Titanium, tantalum, niobium, pelopium, tungsten, molybdenum, vanadium, chromium, uranium, magnesium.
D. Easily fusible or volatile	Arsenic, antimony, tellurium, and bismuth.
E. Malleable.	Zinc, cadmium, tin, lead, iron, cobalt, nickel, and copper.
F. Noble metals, reducible by heat alone . . .	Mercury, silver, gold, platinum, palladium, rhodium, iridium, ruthenium, osmium.

Even this arrangement might be criticized in many ways. Thus aluminium is not placed amongst the malleable metals; but still the metals are arranged according to their predominating qualities, and the difficult question of attempting to classify the metals is certainly disposed of in a satisfactory manner by the author and translator of that colossus of chemical works, Gmelin's "Handbook of Chemistry."

The author has felt great difficulty in selecting from the immense stores of our information on the metals the precise facts that would please and instruct the young, and has therefore endeavoured to carry the youthful reader through the somewhat tedious and lengthy numbers of the metals by giving pictorial illustrations as helps to artificial memory; so that, by merely looking through the pictures of this book, he may gain at once the first and most simple rudiments of a knowledge of the metals.

THE END.

fact, the manufacture of soda for glass and soap making, and as a detergent, is second only in importance with that of iron; and is one of those staple products of industry of which commercial England may be justly proud. Soda is now made by decomposing common salt; but formerly it was wholly obtained by burning sea-weed, and collecting and lixiviating the ashes. The product was called barilla when it came from Spain; kelp, when made on the coasts of England, Scotland, Ireland, and Wales.

Soda is precipitated in a white crystalline state in combination with antimonic acid (SbO_5) as the antimoniate of soda (NaO,SbO_5), provided the solution containing it is slightly alkaline. This test, however, can only be relied on in the absence of all other oxides.

Periodate of potash (KO,Io_7) likewise forms a white precipitate in concentrated solutions of soda.

The most characteristic test of the presence of sodium is a spirit flame, which is immediately changed to a yellow light if a piece of paper moistened with the solution supposed to contain soda is dried and then allowed to burn in contact with it; and still better if the smoke from the burning paper is passed up into a wire gauze chimney whilst the mixed coal gas and air are burning.

As common salt (chloride of sodium) is not only the speciality of the ocean, but is found in all the secretions of the human body, it is considered the characteristic of the animal, just as potassium is thought to represent the vegetable kingdom: at all events, the idea is a good one, and assists the memory in recollecting the sources of these two most valuable alkalies.

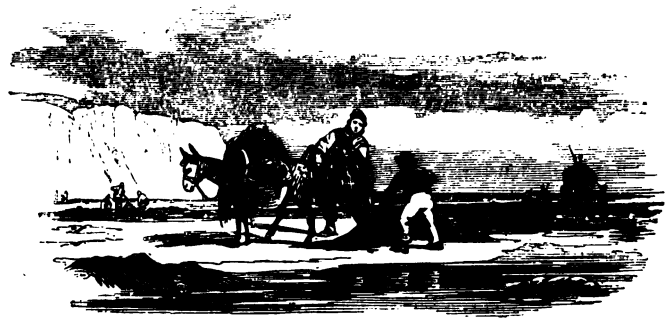
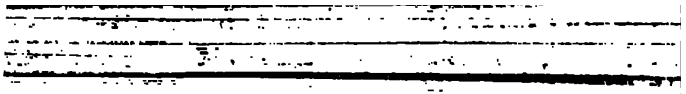
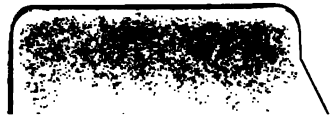



Fig. 256. Collecting and burning Sea-weed on the Sea-shore for the Manufacture of Kelp.